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# SCHOOL SCIENCE AND MATHEMATICS

VOL. XXIX No. 1 JANUARY, 1929 WHOLE No. 246

## SOME NEXT STEPS IN SCIENCE TEACHING.

By OTIS W. CALDWELL,

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The *obligation to distribute knowledge* increases in its complexity. It increases in part because of the astounding growth and readjustment of knowledge itself. What was thought to be true a decade ago may now find itself pushed aside, or incorporated within, or changed in appearance by new truth and new meanings. The obligation to distribute knowledge is complicated by the narrowly segregated and highly intensified divisions of the sciences. For example, most of the productive research workers in chemistry and physics are engaged in extremely restricted problems. Their apparatus, technique and data necessarily separate these workers into small groups, often into groups so specialized that they speak a language which is not clearly understood by workers in other problems even in physics and chemistry, a language which is foreign to other people. The same sort of refinement is true of the work of men in Biology, Geology, Astronomy and Mathematics. Even Education, now ambitious to become a science, has developed groups, some of which have refinements in technique in measurement, in statistical requirements and in standardized forms which close the doors of insight and understanding to all except those who have been initiated into their language and procedures. Such refinements are not matters of complaint or of regret, for they are essential to the growth of knowledge. They do, however, introduce complexities for the teachers of science. These new problems are not always appreciated by the men who are engaged in research

in the different divisions of the sciences. Indeed, the specialized scientific authority of the research man sometimes leads him to dogmatic assertion about educational problems, though these problems are farther from his field of knowledge than are the related science divisions in which he frankly asserts his inability to speak.

We really do need to know, and science teachers are keen to know, what parts of science knowledge should be and can be distributed to the public; what parts should be given to those who hope to become scientific research men; and what parts should be printed only and laid away in libraries for possible use through the future developments in science and education. The problems of what knowledge is of most worth for distribution by education cannot be solved by scientific research men, who, though eminent in highly specialized divisions of science, may be eloquently ignorant of science teaching; nor can these problems be solved through high-powered salesmanship by those whose financial interests in text books or other school materials favor certain types of proposed solutions.

Until a decade or two ago we had so few exact studies of what could be accomplished in public use by any kind of science knowledge that argumentation could be freely indulged in. For sciences in education, it was open season all the year round, and no established rules placed restrictions upon the accepted kinds of firearms or ammunition, and the maimed but-not-killed game was left to recover or die according to its own devices. We do not possess much exact knowledge now, but we have encouraging beginnings. Most important of all, we have the beginning of *belief in exact knowledge* regarding the uses of science in public education.

We cannot expect exact studies to be faultless in a relatively new field. I understand, however, that there is still much controversy regarding validity of methods and results of research in the older special sciences. These criticisms should and will continue, since careful scrutiny helps in disclosing errors. Errors disclosed by adverse critics may be ungracious but are useful. A surgeon isn't thinking much about being kind or unkind while he is operating.

The obligation to distribute knowledge also finds an obstacle in the evolving nature of our citizenship. As education has proceeded with its work we have widened the gap between ignorance and its opposite. And, in a democracy in which the relative

strength of voting is by the number of individuals who vote, and where voting is sometimes a hilarious but uninformed pastime, the efforts to improve the modern knowledge which shall be distributed through education sometimes suffers tragic grief. An educated voter votes no more potently than does an ignorant one, and in times past did not vote so often. It seems a strange procedure to decide what knowledge shall be distributed by the vote of a legislature in which few if any members have any considerable qualifications as students of modern education. Such a procedure has its antithesis in modern educational legislation and management by a university or college board of trustees, all or nearly all of whom are trained and successful business men, who meet occasionally and usually confidently ratify the actions of the institutional head who acts in the names of the members of the board. In both extremes more intelligent cooperation is needed from those who have assumed responsibility. One commonwealth has recently voted by popular referendum that certain biological ideas shall not be a part of that state's distributed knowledge. If the law is enforced not only must modern text books be ruled out but dictionaries, cyclopedias and magazines, since these include the objectionable references. In another commonwealth, made conspicuous during recent years by its efforts to enforce the decision of its popular majority on the same biological question, biology seems now to have performed a highly instructive and amusingly appropriate demonstration. A reliable publication under date of November 17, 1928, reports that: "A human tail of almost record-breaking length has just been discovered appended to a baby girl born at Knoxville, Tennessee. This tail was reported to be seven inches long." This is one of about twenty-five authentic cases of this sort known to biological science. Mother Nature must have sensed the necessity for a demonstration, and must have had her geographic knowledge well in hand, as she presents this seemingly closer touch with the biological past.

Possibly it is our system of suffrage and not so much our educational system to which attention needs to be directed. Even so, we can scarcely expect help from any such consideration. Rather have we adopted the policy of general education for everybody, hoping that we may spread enough education to produce an informed use of suffrage.

Organizations have published propaganda claiming that an elementary school education is good for everybody. It is not

likely that anyone will seriously oppose universal literacy and a modicum of knowledge and understanding of human history. The propaganda are also designed to show increased money earnings for those who have had high school, college and graduate education, indicating that the more education one has the more money he may earn and the more of the world's goods he may command. It has occurred to but few people that on this basis of argument Gene Tunney's line of training or that used by Rothstein might be still better than public education. Gene Tunney, an erudite gentleman, made large earnings outside the plans set up by his formal schooling, and Rothstein, a recently murdered gambler, made huge sums of money by his sharpened wit, but it is reported that he could not write his name upon his own will. In referring to college education Will Rogers says: "You spend all these years playing football and then you go through life waiting for somebody to give you a signal."

Present tendencies indicate that secondary and college education are about to be asked whether they are worthwhile for all who participate in them. It is possible that we are in the latter days of a nation-wide movement to provide education for everybody and to try to get everybody to take it. Dr. Harold F. Clark has given some years to a study of the validity of the claims that all should have all the schooling they can secure. The results, partly published, open very large questions for further consideration. Science subjects, as other subjects of study, will be inspected with reference to whether some of the people now studying them might not more profitably do something else. Then, possibly some of those now doing something else might more profitably engage in science study. These questions will concern the future of science teaching. Unless the subjects studied and unless the whole secondary and college program produce an economic, an aesthetic, or some other kind of helpful social return to the individual or the state, or both, our educational procedures must be questioned. These returns from education to the state or to the individual, or both, must be proved to be not only better than would have resulted without the schooling, but must be enough better to justify the money and time invested by the student and by the state. Dr. Clark's study seems to show that when we take account of inherited capacities of those who *do* and those who *do not* go through high school and college, the case for secondary and college education is made positive for but a part of those who have enjoyed it.

As possible inference, it may be that many people would be better off, and the commonwealth also better off, if fewer or possibly different people went to high school and college. As another inference, the question arises as to what subjects in high school and college produce desirable returns, and what ones do not; also what subject adjustments might possibly be made so that desirable returns may be had for the time and money consumed.

It is possible that Dr. Clark's investigations, and others to be made in the same field, may constitute an influence of the greatest importance in the next decade of American Education. Nowadays, all want to go to high school and college. It is socially the thing to do. This American habit must be justified or corrected. In this adjustment the sciences, which have so much to do with the life of our day, cannot fail to be affected. Specific investigations will be needed to determine what may be proved of economic, aesthetic, and community value.

Another type of important investigation deals with the *content of science text books*. Some of these studies have produced data which from now on will need to be known by those who undertake to produce courses of study and printed materials for pupil use. The most useful text books will no longer be made by condensing into one volume all the significant topics and major principles of a subject, neither will they be made by an eminent scholar who has shut himself in his office and written into his book just what he thought it would be nice to have the book include. No doubt we shall continue to have enough books of the older type to remind us that not all vestigial structures are anatomical.

As one illustration of modern methods of finding what should be the content of a science subject, a monograph now being printed is cited. This study, made by Dr. F. D. Curtis, is a synthesis of 18 different investigations of the desired content of the introductory science course for junior high schools.

As basis for this study the author included 4 published curricular investigations, each of which was a comprehensive study of the available outlines used in introductory science. He included 3 syllabi made relatively recently in representative school systems; 6 published analyses of pupil attitudes and interests; 3 published analyses of the kinds of science knowledge now being used by the general public; 1 published analysis of the science knowledge which the consumer needs for his education, and 1 study of the science topics high school

students regard as of most significance to themselves.

An ingenious and refined method of evaluating and weighing the results of each of the 18 reports was used. The results were synthesized so that the relative rank and weight of all topics was determined. When we recall that 1850 topics had to be tabulated and that statistical technique requires most careful and extended computations, the large amount of work done may be appreciated. For example, in a single one of the tables of values that is presented, several thousand separate computations were made. As a passing corollary it is noted that one can scarcely study the modern curriculum without some real knowledge of mathematics.

Dr. Curtis' synthesis is being published in a monograph in such detail that any curriculum worker or text book writer may use it in his own further work. It will be found valuable in its technique, in its guidance to text book making, and in its contribution and guidance to other curricular studies. By a number of such exact studies determination of curriculum content may soon have acquired a reasonable degree of scientific foundation. During the past six or eight years we have had many general addresses on program of popular general education, dealing with the content of the curriculum. The popular educational speaker will soon shift to new hunting grounds, probably character education, since a few facts are beginning to limit his freedom with the curriculum.

Science instruction seems likely to gain from *studies of the vocabularies in common use.* We must keep in mind that this type of study is not new. Professor H. G. Good of Ohio State University calls attention to a fundamental vocabulary study by Richard Mulcaster, published in London in 1582. Mulcaster compiled "lists of the most frequently used words." He made these lists from analyses of common usage in speech and writing. He then urged that school subjects should make sure that pupils may learn and use these words found by him to be those of common need. It is most interesting to compare Mulcaster's lists with those prepared in our day by such eminent students as Thorndike, Ayers, and others. Of the 1,000 common words listed by Ayers, 527 are found in Mulcaster's list prepared over three hundred years before, and in another country. If certain discarded or slightly changed word endings are ignored, Mulcaster's list contains 756 words of the Ayers' list. Of the 1,000 words, which according to Thorndike are most commonly used

in speech, in print and in writing, Ayers' list includes 672, and Mulcaster includes 857. Ayers has in his word list 328 words which Thorndike does not include in his first 1,000, while Mulcaster has but 143 words not in the Thorndike list.

Such studies of vocabulary have recently been applied to science and mathematics. Remmers and Grant, in a study just published, analyze the vocabulary load of certain mathematics textbooks. Powers, Curtis and others have reported vocabulary studies of science textbooks. Two significant results are derived from these studies. First, the vocabularies used in textbooks greatly exceed the vocabulary range that is in common use by the average pupil who uses these texts, and secondly, many unknown terms are not well-explained when used and are not used often enough to give familiarity with them.

All agree that the heavy load of un-understood or misunderstood terminology must be corrected. There is much difference, however, as to thought of how the correction shall be made. Some critics have drawn the conclusion that all printed material in science and mathematics, to be placed in the hands of pupils, should be written within the average pupil's vocabulary range. Some of these studies go so far as to exclude such words as inherent, erroneous, harmonize, deleterious, accelerate, impervious, tenaceous and fluctuate, and hundreds of others like these, because these words do not appear in the standard 10,000 word list. Others do not agree to this inference and point out first that the whole educational system is now emphasizing better reading ability thus increasing the vocabulary range. Reading ability is essential to any considerable progress. New words and terms are essential and are desired by learners as new ideas and processes are acquired. Frequent use of new terms is essential to real acquaintanceship. Each science and mathematics subject possesses ideas, processes, conclusions and applications peculiar to that subject, and each subject needs some new vocabulary with which to give clear expression to these. Why do pupils study new subjects if not to acquire the ideas and abilities the subject may give them; and if they do so, why not give them the tools for expression of new ideas. Professor W. W. Charters summarizes this question as follows: "One of the major functions of education is to assist students to develop an intelligent use of an increasing range of words. If a student is to understand a subject, it is essential that he shall know the technical terms which are necessary to describe exactly the content of

the subject. It is a function of education to increase the vocabulary of students through the study of subject-matter. The instructor in charge of courses frequently appreciates the value of increasing the student's vocabulary much more fully than he appreciates the necessity of confining his discourse to words which the student understands."

Vocabulary studies are having a wholesome effect in causing teachers and writers to inspect the vocabulary they use and to give attention to adequate understanding and repetition of new terms. If what the pupil learns accurately is the real test of education, the futility of using words and language foreign to him is obvious.

Another important study which seems almost certain to be a factor in the next steps in science teaching relates to the nature and extent of pupils learning *a scientific way of doing things.* Dr. E. R. Downing, in the March, 1928, Scientific Monthly, has an unusually clear analysis of the factors of this method and describes ways of developing it. As science teachers we have talked much and done little about transmitting *to,* or developing this method *with* students in general. We have been quite unscientific in our discussions of the ways in which people learn to use scientific methods. Studies such as those proposed by Dr. Downing and others may possibly prove whether and how the method may be taught.

Investigations seem likely to *redirect attention to the training of science teachers.* Dean M. E. Haggerty has made a study of what becomes of the doctors of philosophy from the universities of Minnesota, Chicago and Harvard. He finds that approximately seventy-five per cent of all doctors from these three outstanding institutions go into teaching. The percentage at Columbia is still higher. Most of those who take masters degrees go into teaching. Studies made by Edmondson and others show that even the bachelors degree is precedent to teaching more than to any other calling. An editorial comment says: "The Ph. D. knows the principles, the abstruse problems, and esoteric information of his field. In these he is competent. To adapt what he knows to undergraduates is a different problem. In the solution of this he is amateurishly incompetent." (W. W. C. in Ohio Ed. Res. Bull., Nov. 14, 1928.)

In his monograph on "Biology in Secondary Schools" Dr. C. W. Finley has presented an excellent study of the science teaching situation. Other studies have shown that teachers' salaries

have advanced so that really well-prepared teachers may find financial support which will give them reasonable opportunity, fair, but not enough leisure for study, and advances usually commensurate with their growth in scholarship and teaching efficiency.

It seems safe to conclude from the studies available that in the future we shall give more, not less emphasis to scholarship in the science subjects, and more emphasis to the scientific study of problems in teaching. But scholarship will be gained in part at least in terms of the teaching situations for which it is to be used and will be learned in part while studying the teaching problems themselves. The State Teachers Colleges are already preparing many science teachers and will probably prepare a larger percentage of them. Scholarship in science knowledge is being encouraged in the Teachers Colleges. In the Liberal Arts Colleges the needs of educational studies must be encouraged. Unless these needs are encouraged in the Liberal Arts Colleges, the present tendencies seem likely to reduce the service Liberal Arts Colleges are giving to preparation of science teachers. Merely ignoring the present situation in preparation of science teachers may gradually eliminate a college so doing from participation.

There have been many separate pieces of research regarding the science curriculum. The best summary of those is found in Dr. Curtis' volume, "A Digest of Investigations in the Teaching of Science in Elementary and Secondary Schools" published in 1926. We need such survey volumes to appear each three or four years. We need this in order to make new investigations available and to keep us up to date regarding the relation of the new to the older investigations. Published research does not reach all who would be helped by it. Then there are unpublished theses which can be summarized in such a survey volume. If those who give teacher training courses regard such survey volumes as useful to their students it is likely that these volumes will continue to appear. Have we not reached the time, however, when we need something more than such investigations as are appearing from scattered and wholly independent workers? We shall, we hope, continue to have that type of valuable contributions. We need a few science teaching research centers in different parts of the country, each with a far-reaching program of research and teacher training. We need these for the sake of the new knowledge they will produce. We need then in order

to accumulate valid techniques of research. We need them as centers to which ambitious younger science teachers will look for help, and to which those interested and qualified may go for a time for their own productive studies.

We have centers now being developed in such universities as Chicago, Stanford, Minnesota, Columbia, and elsewhere. As illustration of my meaning I quote from a forthcoming paper by Dr. S. E. Powers. "There is need for careful analytical study to determine the major conceptions and generalizations which science has contributed and there is need for an evaluation of these which shall determine the ones that are of most consequence to general training. It is not sufficient for us to say that science has completely transformed our manner of living. Curriculum workers must state as their objectives the conceptions and generalizations which have accomplished this transformation and they must array learning experiences which will contribute the largest possible understanding of them."

"There is need for research which will reveal clearer definitions of the scientific attitudes and for research which will reveal the teaching situations by means of which the learner may come to a functional understanding of them. The same point of view is applicable to discussion of scientific methods. There is need for definition of the elements of the scientific method which are functional for individuals who are not employed as special workers in one of the fields of science."

Similar questions relate to the problems of directed study, the contract plan, etc. These are to be recommended provided they incorporate devices whereby the teacher may most effectively provide the richest learning experience. Textbooks, tests and the library should all be evaluated in terms of the same general principle, what learning experiences may each contribute which will result in more complete accomplishment of definable objectives."

The American Association for the Advancement of Science has recently given serious attention to the place of science in education, and appointed a committee of its own members to deal with the questions involved. This committee has conducted programs, published brief reports and otherwise endeavored to encourage thought about science in modern life. In its last report this committee makes three important recommendations: that some organization of wide scope be asked to make a careful study and comprehensive report upon the present tendencies and

anticipated needs of science instruction in educational systems; that a national council of science teachers be organized to increase public appreciation of science and to secure increased facilities and wider usefulness for science teachers; and that a science field secretary be secured to work with existing agencies in distributing information, stimulating research and serving as a clearing house for all sorts of science interests in education.

Already, the first recommendation seems likely to be cared for in the territory of the North Central Association of Colleges and Secondary Schools in case a proposed plan is adopted at the next meeting of that association. Nothing has yet been done regarding the council, or the field secretary.

The Council of the A. A. A. S. has recently appointed an Executive Committee to deal with science education. This committee consists of Dr. B. E. Livingston, Permanent Secretary of the A. A. A. S., Dr. J. McKeen Cattell, Dr. Elliot R. Downing, Dr. Ira W. Howerth, and Otis W. Caldwell, chairman. It is not the purpose of this committee primarily to prepare reports for publications, but to stimulate and help all movements looking toward better distribution and use of science knowledge.

To *measure* what and how pupils learn still seems a vision to many science men. This is now being effectively done in some subjects. To have a scientifically determined science curriculum seems a buoyant hope. May I call attention to what a great scientist, Professor Simon Newcomb, said in published articles in 1901, 1903 and 1908. He was speaking of the possibilities of successful airplane flights. He said:

"I have shown that the construction of an aerial vehicle which could carry even a single man from place to place at pleasure requires the discovery of some new metal or some new force. Even with such a discovery, we could not expect one to do more than carry its owner."

"The mathematician of today admits that he can neither square the circle, duplicate the cube, or trisect the angle. May not our mechanicians, in like manner, be ultimately forced to admit that aerial flight is one of that great class of problems with which man can never cope, and give up all attempts to grapple with it?"

"The writer cannot see how anyone who carefully weighs all that he has said can avoid the conclusion that the era when we shall take the flyer as we now take the train belongs to dreamland."

The impossible has become a fact. What once seemed impossible in science teaching may be accomplished.

*What is it which modern science is trying to accomplish?* Science in education as in the growth of knowledge of special sciences, is trying to encourage the spirit of inquiry, the desire to know, the ability to ask and answer questions for the sake of answers, but chiefly as these answers increase interest and ability in answering other questions. Science recognizes that continued evolution of human mind depends upon the continued use of mind in inquiry, in conclusion, in applications, in the establishment of new truth. Science accepts Poincare's statement that "man is the measure of his own universe."

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## FROM THE SCRAPBOOK OF A TEACHER OF SCIENCE.

By Duane Roller,

*University of Oklahoma, Norman, Okla.*

The object of mathematics is to prove that certain premises imply certain conclusions; and the fact that the conclusions may be as "obvious" as the premises never detracts from the necessity, and often not even from the interest of the proof.—*G. H. Hardy, mathematician, in "Pure Mathematics."*

Scientific law is description, not prescription.—*Karl Pearson, "Grammar of Science."*

Old sciences are unraveled like old stockings, by beginning at the foot.—*Jonathan Swift.*

Astronomy is one of the sublimest fields of human investigation. The mind that grasps its facts and principle receives something of the enlargement and grandeur belonging to the science itself. It is a quickener of devotion.—*Horace Mann, American educator.*

These earthly godfathers of heaven's lights,
That give a name to every fixed star,
Have no more profit of their shining nights,
Than those that walk, and wot not what they are.
—*William Shakespeare, "Love's Labor Lost."*

Science has no nationality because knowledge is the patrimony of humanity, the torch which gives light to the world. —*Louis Pasteur.*

Why is it that we entertain the belief that for every purpose odd numbers are the most effectual.—*Pliny the Elder, "Natural History."*

Round numbers are always false.—*Samuel Johnson.*

# A STUDY OF ACHIEVEMENT IN GENERAL MATHEMATICS.

By Jane M. Crow, M.A.,
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and

August Dvorak, Ph.D.,
*University of Washington, Seattle, Wash.*

Since the appearance of the General Mathematics, a reorganization of the subject matter of mathematics for the seventh, eighth, and ninth grades, there has been a difference of opinions as to the advisability of such a change among leaders in this branch of education. Arguments for and against it have seemingly been based largely on more or less expert opinion. No definite comparative study of the achievements of pupils trained with the old and new types of subject matter has been made until recently. This study was a comparison of achievement in certain phases of mathematics between pupils who had studied General Mathematics and pupils who had studied the older type of organization—Algebra and Geometry. The study was carried out by giving the same standardized tests in Mathematics to groups of pupils trained with the old and the new type of subject matter, and by comparing the scores thus obtained in each group of pupils.

The "Hotz First Year Algebra Scale,"[1] and the "Minnick Geometry Tests"[2] were given to the pupils involved in the study. The Hotz Scales are based upon the formula which constitutes a very large part of the first year's work in Algebra. The Scale is divided into five parts: Test I, "Addition and Subtraction"; Test II, "Multiplication and Division"; Test III, "Equation and Formula"; Test IV, "Problems"; Test V, "Graphs." The first four parts were used in the study. The geometry tests are divided into four parts and stress four important phases in geometry—Test A, "Constructions"; Test B, "Stating the Given and to Prove Steps"; Test C, "Stating Facts About a Given Construction"; and Test D, "Giving the Proof." All four parts were utilized in this study.

The four parts of the "Hotz Algebra Scale" and four parts of the "Minnick Geometry Tests" were given to pupils in eleventh and twelfth grades who, at that time, were not taking advanced

[1]Hotz, Henry G. "First Year Algebra Scale." Teachers College, Columbia University. Contribution to Education No. 90.
[2]Minnick, John H., University of Pennsylvania. "Geometry Tests." Public School Publishing Company, Bloomington, Ill.

work in mathematics. The following schools cooperated in the study: West High School and University High School (associated with the University of Minnesota), Minneapolis, Minn.; Senior High School, Kirksville, Mo.; Okmulgee High School, Okmulgee, Okla.; and Roosevelt High School, Seattle, Wash. The students in the first three schools given above had studied general mathematics; those in the other schools had studied algebra and geometry.

The tests were given to regular class groups found in the high school organization. Because of problems connected with the isolation from the whole regular class groups of Juniors and Seniors who qualified for the study by virtue of no additional mathematics training after the tenth grade, a total of 193 different students took the geometry tests and 272 different students took the algebra tests. An attempt was made to secure the Intelligence Quotients of all the students who wrote on the tests. These were not available for all the students. A comparison of the intellectual ability of the two groups therefore was impossible because of the lack of these data. The lack of groups identical in number, in mental ability, in background of training, and in several other variables that might or might not influence the achievement in mathematics of different pupils is the outstanding weakness in this study. This weakness will consequently necessitate that, until verified, these results be taken as tentative. The justification for presenting them now, is the complete lack of data relative to the comparative achievement of pupils trained by the old and the new type of Secondary School Mathematics.

Each of Minnick Geometry Tests is scored on the basis of positive and negative score. The positive score is computed on the basis of 100 points for perfect performance of each test. The negative score is the number of incorrect or unnecessary statements. The Hotz Algebra Scales are scored on the number of problems done correctly. In this study Group I is the group of pupils who had studied General Mathematics and Group II is the group of pupils who had studied Algebra and Geometry.

To facilitate the reaching of as precise conclusions as possible, the median score on each test for each group was computed. It soon was evident that the differences between the medians of Group I and Group II were not only small but more or less equally divided in favor of the one and the other group.

The method suggested by McCall[5] which, by means of the standard deviations of the Difference between the medians, computes an Experimental Coefficient which in turn is an index of the probable ratio of chances that the larger median is occasioned by real superiority of its group and is not caused by pure chance, was used. The test results follow in tabular form:

| TESTS | Med. Score Group I | No. of cases Group I | Med. Score Group II | No. cases in Group II | Diff. between Med. favor Group I | Stan. deviation of Diff. | McCalls Exper. Coef. | Chances that Group I was Superior | Chances that Group II was Superior |
|---|---|---|---|---|---|---|---|---|---|
| GEOMETRY | | | | | | | | | |
| Positive Score | | | | | | | | | |
| Test A | 61.7 | 115 | 61.6 | 78 | .1 | 3.1 | .012 | *insig. | ........ |
| Test B | 69. | 53 | 65.5 | 70 | 3.5 | 3.1 | .35 | 3.9:1 | ........ |
| Test C | 63.5 | 53 | 63.9 | 70 | −.4 | 4.6 | .03 | ........ | *insig. |
| Test D | 69.5 | 53 | 65.5 | 70 | 4. | 4.9 | .33 | 3.9:1 | ........ |
| Negative Score | | | | | | | | | |
| Test A | 5.5 | 115 | 4.2 | 78 | −1.3 | 1.18 | .4 | ........ | 6.5:1 |
| Test B | 2.9 | 53 | 2.3 | 70 | −.6 | .56 | .4 | ........ | 6.5:1 |
| Test C | 2.5 | 53 | 2.4 | 70 | −.1 | 1.1 | .03 | ........ | *insig. |
| Test D | 2.6 | 53 | 2.9 | 70 | .3 | .58 | .1 | 1.6:1 | ........ |
| ALGEBRA | | | | | | | | | |
| Test I | 6.5 | 57 | 5.5 | 145 | 1.0 | .47 | .76 | 38:1 | ........ |
| Test II | 6.3 | 57 | 5.2 | 145 | *.1 | .42 | .94 | 160:1 | ........ |
| Test III | 6.5 | 57 | 5.2 | 145 | 1.3 | .46 | 1.01 | 369:1 | ........ |
| Test IV | 5.4 | 119 | 5.04 | 153 | .36 | .268 | .48 | 6.5:1 | ........ |

*The Experimental Coefficient is so small that the chances favoring either group are insignificant.

A study of the table shows that in eight scores computed for each child taking the geometry Test, and in Test IV (problems) in algebra General Mathematics pupils had slightly or no greater chance of being superior in achievement to the algebra-geometry pupils. In tests I, II, and III in algebra (Addition and Subtraction, Multiplication and Division, Equation and Formula) the chances are decidedly in favor of Group I being superior to Group II. It is to be noted, however, that McCall's Method tries to establish the fact of superiority and not the amount of superiority. The differences between the medians of Group I and Group II are very small, indeed. If it were suggested that the chances were computed so that the median of Group I pupils will be more than 5 points superior in positive scores in Geometry, and more than 1 score superior (less in number) in "Negative Score" and 1 point superior in Algebra, it is evident from a study of the column, "Difference between Median favor Group I,"

[5]McCall—How to Measure in Educ. 1922. Macmillan Company.

that all but three of the figures in the last two columns would have been in favor of Group II. In other words, while the chances are somewhat in favor of Group I, being superior in whatever abilities were measured by the tests used, the chances are not preponderous, and the difference in Median achievement is, indeed, very slightly in favor of Group I and is menaced by the actual superiority of Group II in four of the tests. The question can then be raised, "Is there sufficient superiority of method, organization and selection of content to justify the enormous changes in mathematics teaching that are now being advocated?" and "Are there other merits in the reorganized or General Mathematics which offset the apparent lack of superior achievement?"

It would seem, therefore, that the advocates of general mathematics would have to modify their claim in respect to the superiority of General Mathematics or else advance some conclusive evidence for such superiority. Yet some facts which may be deduced from the study are gratifying. The experiment tends to show that the reorganized mathematics gives the pupil as much knowledge in this subject as the old type of organization, though no decided advantage. Several reasons may be offered as an explanation to this.

In the first place, mathematical instruction is in a period of transition. The junior high school movement, with its changes in curricular and administrative features, is one cause of this transition. The reorganized subject-matter in mathematics is another cause. Of the General Mathematics textbooks written by such authors as Schorling and Reeve, Wentworth Smith and Brown, and Breslick, and used by the three groups of pupils in this study who were taught General Mathematics, one or two of the books are already being discredited by some advocates of General Mathematics.

The lack of teachers who were trained in the content of General Mathematics, and later were trained in the teaching of General Mathematics, is another limitation that may interfere with the success of General Mathematics. But few books are written on the teaching of junior high school mathematics. The teacher must be prepared in and beyond the mathematics he or she actually teaches. Success requires richness, enthusiasm, and determination. "The desired results will never be achieved until there is a modification of the teachers themselves."[4]

[4]Birch, John N. "The Problems of the Algebra Instructor." Mathematics Teacher, Vol. XX, No. 3, March, 1927.

The difference between the experimental coefficients of the two subjects is an interesting result of the study. The experimental coefficients in the algebra scale are much higher than those in the geometry tests. This may indicate that the subject matter dealing with algebra in the new texts in General Mathematics carries over better than that on intuitive geometry. This difference may be due to the manner in which it is taught, or to the fact that individuals have opportunity to put algebra to practical use more times than they do the geometry they study. Again the difference may be due to the fact that in the algebra-geometry group (Group II) the algebra was at least one year removed from the time of testing while the geometry was more recently fresh in the pupil's mind whereas, in Group I, due to the organization of subject matter, both algebra and geometry were fresh in the pupil's minds, having recently been studied concurrently.

If, from the investigation, we conclude that the new organization as it is given in general mathematics is as good as that in the regular tests, then there is a bright future for the elective plane geometry course in the senior high school. The emphasis can change from the demonstration of theorems to the wide field of problems offering opportunity for interesting and practical use of the theorems studied.

One other conclusion may be drawn from this study in regard to college entrance for the general mathematics student. Any principal of a high school can certify that the work is equivalent to the required standards. Mathematics, however, is a subject that is easily forgotten. Hence, the student who studies general mathematics or algebra in the Ninth Grade and takes no other course of mathematics until he reaches college is sure to have trouble. Schorling[5] in speaking of the General Mathematics students from the University High School, Chicago, says that those individuals who study no algebra or geometry text as we commonly think of them, make good records in the University of Chicago, and that pupils in the Lincoln High School, New York, who study general mathematics in the Seventh and Eighth Grades, and a modern type of algebra in the Ninth Grade, make good records in Yale, Harvard and other higher institutions of learning.

Such evidence, as this study is able to advance, indicates

[5]Schorling, Raleigh, "General Mathematics." The Mathematics Teacher, Vol. XX, No. 2, February, 1927.

that the pupils who have studied general mathematics show ability at least equal to that of the geometry-algebra pupil, and since the new type of subject matter offers a splendid opportunity for motivation, is for the child interesting material which broadens his view of the subject, it seems safe to conclude that General Mathematics is justified a tentative place in the high school curriculum. The place in the curriculum, however, ought to be challenged and considered tentative until really scientific studies of quantitative nature, absolutely lacking today, show that the place of General Mathematics deserves to be permanent.

## CARRIERS FOR COLDS.

When colds "run in the family" it is no sign that the family is constitutionally subject to colds. It may be that some member of the family is acting as a carrier, just as some people are typhoid carriers, suggests Dr. P. Watson-Williams in a report to the *Practitioner* (London) of observations made on ninety consecutive patients. Sometimes one child is known for starting colds among his brothers and sisters. This same child may become immune to colds himself but still harbor cold germs and be able to pass them on to others. If he grows up and has a family, he may still be starting colds in the family, although they are no longer traced to him.

The reason for this may be an unsuspected infection of his nasal sinuses, the honey-comb structures back of the nose and eyes. This same infection may be the reason for some children growing a second set of adenoids, when the first ones have been removed with the tonsils, Dr. Watson-Williams thinks.

Dr. Watson-Williams also reports a tendency for families that are prone to colds to have infections, in the abdomen, for instance in appendix and gall bladder.—*Science News-Letter.*

## TERRE HAUTE TEACHERS ENJOY SABBATICAL LEAVE.

Sabbatical leave as recently adopted by the school board of Terre Haute, Ind., may be granted for one year of study to any member of the teaching, administrative, supervisory, or library staff, after seven or more consecutive years of successful experience in public schools of the city. For each subsequent period of service of seven years or more an additional leave may be granted for study or professional advancement. The leave of absence, if desired, may extend over only a half year. During absence on sabbatical leave the regular salary will be paid, less the amount paid to the substitute. The time of such absence will count as regular service toward retirement, and full contribution toward the retirement salary shall continue during the period of leave. Any person to whom such leave is granted may have his old position upon return to school work if he desires it.—*School Life.*

## SOME THINGS SCIENCE STUDY SHOULD DO FOR THE STUDENT.*

By Harvey L. Long,

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Antoine Lavoisier, noted French scientist of the 18th century, the founder of modern chemistry, was interested and active in the political affairs of his country. Unfortunately for scientific progress Lavoisier's career was brought to an early end by way of the guillotine at the hands of the revolutionary government in 1794.

But there was one to come after Lavoisier. Some 70 years after the death of Lavoisier, J. B. Dumas called upon Louis Pasteur, then a young professor, to join with him in an edition of Lavoisier's works. Pasteur was born in 1822, 58 years after Lavoisier's death. 100 years after Lavoisier's first discoveries Pasteur was a young chemistry student. That he studied and was inspired by Lavoisier's art is apparent from the letter which Dumas wrote asking Pasteur to collaborate. "'No one' wrote Dumas 'has read Lavoisier with more attention than you have; no one can judge of him better.'" Pasteur consented to collaborate but plead for time.

"Dumas replied, 'Dear friend and colleague, I thank you for your kind acquiesence in Lavoisier's interests, which might well be your own, for no one at this time represents better than you do his spirit and method, . . . . . a method in which reasoning had more share than anything else . . . You possess this method to a degree which always gives me a pleasure for which I am grateful to you.'"

Pasteur was inspired, however, by more than Lavoisier's art of experiment. The man himself filled Pasteur "with a new and vivid emotion . . . . Concerning such a man as Lavoisier, Pasteur's curiosity became a sort of worship." What were the results? Lavoisier had said "We ought in every instance, to submit our reasoning to the test of experiment, and never search for the truth but by the natural road of experiment and observation."

This germinal statement became the mustard seed of Pasteur's career. We have this philosophy, this spirit, to thank for what has been generally conceded the most important discovery ever

*Read before the Science Section, N. S. T. A. session, November 3, 1927

announced (e. g., the disproval of spontaneous generation; the origin of aseptic surgery and the germ "theory" of disease).

Pasteur had announced his disbelief in spontaneous generation. In 1858 M. Pouchet sent to the *Academic des Sciences* a paper affirming that he had produced spontaneous generation. Pasteur replied to Pouchet "That the results which he attained were not founded on facts of a faultless exactitude. I think you are wrong not in believing in spontaneous generation (for it is difficult in such a case not to have a preconceived idea), but in affirming the existence of spontaneous generation. In experimental science it is always a mistake not to doubt when facts do not compel affirmation."

You see Pasteur had pushed Lavoisier's remarkable statement further.

These remarks about Pasteur illustrate at least three things which are pertinent to science teaching.

The first of these has to do with what the pupil has become as a result of his study of science. As a result of his study, Pasteur had some facts of course, but what was of greater worth he had developed an insatiable desire for more information, for further science study, and had found a technique, a formula, a guiding principle, a method of systematically attacking problems; had developed an attitude of mind so essential to the discovery and recognition of truth. Are we attempting to do as much for our pupils?

I am confident that an investigation would show that teachers of Junior and Senior high school science have been attempting to give children a great mass of facts, minor details, expecting that all will be remembered and used. Our tests have been largely to determine whether these detailed facts have been mastered. I am not objecting to the teaching of a great assemblage of facts. What I am objecting to is the emphasis and the aim in mind while these facts are being "taught." If an array of facts is given to illustrate a general truth, or develop an appreciation, and we test for the thing sought we are then going in the right direction. The temptation for a beginning science teacher is to give to his pupils all the details that he mastered as a result of many repetitions and many courses. If the teacher has a special interest, "weather" for instance, he may feel that he has failed and not accomplished a thing, if all of his eighth grade pupils cannot read a weather map and predict the weather a week after completing the subject.

It should be a source of satisfaction to the teachers who have been striving for mastery of details; the specific application of principles, etc., to hear Professor Snedden provisionally uphold, "as a probable sound hypothesis that the greatest single source of confusion and futility in the teaching of natural science in elementary and secondary schools within recent years has been failure to distinguish *appreciational* from *performance* objectives."

Mr. Snedden believes that in certain grades "science should be presented to pupils under such pedagogic methods and standards of attainment that the chief learning products will be appreciation rather than intellectual grasp of abstract principles or other formal knowledge." (Snedden, T. C. Record, 1927, page 812.)

In other words, mastery of cold bare facts is not the important outcome of science study. The mere conception of one idea, the understanding of a great principle as a result of many experiences in the classroom, may be the biggest outcome we can strive for. This is particularly true if this discovery and revelation is one that opens the way—and leads on.

Pasteur's experience illustrates a second thing pertinent to science teaching. We noted in the foregoing that Pasteur was "filled with a new and vivid emotion concerning such a man as Lavoisier." One can read a mere recital of the facts concerning germs causing a disease without being much impressed. A "germ" is just a "germ." But to read about "germs" in connection with the one who discovered so much concerning the life activity of micro-organisms adds a humanistic element which makes the study of the facts a romance. One cannot read of his home life, of his disappointments, of his unselfish achievements, of his filial devotion, his physical suffering, of his pioneering, of the honors he received, of his elegant nationalism, of his international fraternalism, without being filled with a new and vivid emotion concerning Pasteur.

It is apparent from the biographies of men who have made a real contribution to the world that great influence upon their careers has come from actual or vicarious contact with some person who was a source of inspiration. This is true almost without exception. It is noted in many cases that these influences came at an age which corresponds to our Junior High School age. Further, as in the case of St. Paul, Comenius, Pasteur and others, the source of inspiration to a youth has often been a person who lived in a generation that had passed before his birth.

The story of the accomplishments of men of science is a source of the world's greatest romances. If a teacher fails to humanize science by bringing in vivid stories of the lives of men who have made it, he has not only failed to exploit an excellent teaching aid but has neglected an opportunity to present possible sources of great inspiration.

Who can measure or test the results that come from either a real or vicarious contact with an exemplary life?

The third thing in the foregoing story from Pasteur's life that is of significance in science teaching is the value of an appreciation of how truth has been arrived at.

In his vicarious contact with Lavoisier, Pasteur saw how most of Lavoisier's accomplishments were the result of many, many generations of study and research. That Lavoisier was able to build certain chemical principles, to draw certain conclusions because of the work of his forerunners and contemporaries (such as Priestley in England). He saw the rough and tortuous road over which one slowly travels toward truth, sometimes arriving to find the truth still just beyond. In other words, Pasteur learned his chemistry not by getting actual statements from a text book but by reference to the published accounts of the original researches. He followed the steps through which his predecessors went to arrive at the facts. This did three things for him; it gave him an understanding of the facts, how they were ascertained and a cue as to what and how progress could be made.

The uninitiated are apt to take our present stock of information for granted. Suppose you should ask a boy why we know as certain thing to be true. He would likely reply, "The book says so." The printed page becomes the authority—the sacred revealing source of information. What increased significance would a fact have if children were given an appreciation of how it was arrived at after ages of superstitution and grotesque explanation. What increased reverence for truth with a passion to know the truth might result if one aim and purpose of the science teacher should be to lead his pupils "to seek and know the truth."

At no time in this paper am I discounting the necessity of insuring that pupils acquire the factual information necessary to cope with the unprecedented conditions that are found in modern society. But science study that begins and stops with facts,

just as science study that begins and stops with generalizations alone, will not give such insurance.

Psychology has made plain that a fact taught out of its relationship is apt to be of little value in general life situations and may remain unapplied even when a pertinent situation arises. Mr. Slosson says that science consists in showing relationships and that the "Unity of Nature" is the gospel needed in elementary science teaching (Sch. and Soc. 12-27-24). For instance, oxidation may be "taught" as a chemical reaction of which burning wood might be used as an example. Or it may be "taught" as a vital process in human metabolism. You will agree with me that no pupil will have a "unified" view of oxidation until he has observed that not only is the burning of wood, coal, gas, gasoline, etc., in modern machines an oxidation process but that the biological release of energy is an "oxidation" process (whether in decay caused by microörganisms or in the use of food by higher animals) and that rusting or corroding of metals is often an oxidation process as well.

An appreciation of the universality and principles of oxidation makes it probable that in the face of a new situation concerning oxidation intelligent behavior may result. When if a few isolated facts concerning oxidation had been taught there would be little probability that the new situation would be solved.

Mr. Slosson adds that it is wrong "to be too fast, forever putting our students through a too rapid pace—putting facts into the mind while never providing time to use them in thought" (Sch. and Soc. 12-27-24). He is saying what the psychologist means when he says that information is more likely to be functional if in the giving of facts, generalizations are made and opportunity is given in the classroom for pupils to use the facts and thus make the generalizations rational. There are few who would attempt to justify the mechanistic mastery of facts of science as a major aim of elementary science, but many of us teach and test as though this were the sole purpose of science teaching. The foregoing point of view is not a matter of philosophy alone. It is supported by scientific observations.

In spite of their reputed idealism Americans are practical people. There is a popular demand that schools give children practical things of immediate worth. May I be permitted to object to the idea that everything "taught" in science must be of immediate practical value. A popular scientific writer makes a trite but meaningless statement in this regard. He says, "Gen-

eral science should keep to the practical as far as practical—and leave the rest to principle." Pasteur in 1854 in his opening address as dean of a new faculty of science in the first school to provide laboratory experimentation for students said to his students, "without theory practice is but routine born of habit. Theory alone can bring forth and develop the spirit of invention."

He urged his pupils further not to be as narrow as those "who disdain everything in science which has not an immediate application—a theoretical discovery has but the merits of its existence, it awakens hope and that is all. But let it be cultivated, let it grow, and you will see what it will become" (T. C. Record 4-27, p. 795).

Franklin was once witnessing a "demonstration of a purely scientific discovery" and the people around him were saying, "But what's the use of it?" Franklin answered them, "What is the use of a newborn child?" (T. C. R. 4-27, 795.)

I am not quoting these three eminent scientists to advocate the teaching of theory to high school pupils, but to point out that there may be value even for Junior high youngsters in giving time to things—apparently not of immediate practical value.

I would like to comment further upon the attitude of mind of Pasteur—which is evident in his reply to Pouchet. We have read much of the "Scientific Attitude" of open-mindedness, etc., implying the use of the methods of science. James Harvey Robinson generalizes from his study of history by saying that we have first to create an unprecedented attitude of mind if we are to cope with our unprecedented conditions and to utilize our unprecedented knowledge.

This unprecedented attitude of mind is according to many sources, that of the good scientist who never commits himself definitely—always conditionally, realizing that, even though only remotely possible, there may be an exception to any generalizations he might make; one who is ready to admit ignorance when he does not know; who has the habit of suspending judgment until the evidence is in making his decision in terms of facts; who prefers facts to "authorities"; who prefers the opinion of the expert to that of the novice; who is sensitive to imperfection and difficulty, etc.

This unprecedented attitude of mind is so important that every teacher whether teaching science or not should aim at its development.

"The public has a right to expect that the graduates of the schools will be able and anxious to secure facts and to think through life problems in the light of those facts. Not the furnishing of a boy with ready made opinions, but his training in the collection and interpretation of facts in order to arrive at an intelligent judgment—that is the school's task.

"Here, as elsewhere, example counts more than precept. The teacher who would have his pupils use the attitude of scientific open-mindedness in all situations must himself demonstrate that attitude in all situations. He will, as far as possible, select his teaching methods and materials on the basis of facts, he will be open to evidence in his dealings with his pupils, he will be open-minded and tolerant in his civic and personal relations." (Cover page of a 1927 Bulletin of Detroit schools).

In my observation the one great fault of experienced teachers is that they oftentimes become indoctrinated and indoctrinate their pupils. They close their minds on a situation and whether intentionally or not have the same influence on their pupils. Having the unprecedented attitude referred to a moment ago, is an accomplishment which will not come as a result of accepting this philosophy. In addition to acceptance, daily practice of habits of acting and thinking is necessary.

I should like to drop a word of warning here. Objective reality is not the whole of the real. "Things are not always what they seem." An unsophisticated youngster may get an impression that he should believe only what can be proved; that his objective observations using his limited senses, are sufficient to interpret his environment. If this were true the world would be flat and the sky a canopy arching over it. Pasteur's reply to Pouchet, "In experimental science it is always a mistake not to doubt when facts do not compel affirmation" does not mean that a layman should disbelieve a thing because he cannot explain or go into a laboratory to demonstrate it himself by proof. Much of our store of knowledge at one time was a result of philosophy. Science has answered by confirmation or disproof much that philosophy once treated. We can say now that we know many things where once we "knew" only as a matter of belief. But there is a great field of reality that science has not yet the tools with which to handle.

I am sure it is a healthy situation when one realizes that he "does not know" when pupils realize that one cannot know everything. But on these items it is not necessarily complimentary

to say "I don't know" or "I don't believe" just because there is no proof, when reason, philosophy and the results of race experience point in a given direction of "belief." Not only must one realize that there is more information in the world than he can hope to master but that there are still many things that must be accepted for the present as a matter of belief. Science study should help the pupil to distinguish between what is a "proven fact" and what is "belief." It should aid him to treat with science, things so many people continue to treat with philosophy when science has already conquered and vice versa. It should bring him along the road toward replacing fear with faith and judgment with reason, knowing like the chemist, that "faith in the unseen molecules is a practical faith that is followed by works."

No one appreciates more than the trained scientist does, to what limitations our ignorance confines us; that though we do know much there is much we know only relatively and more that we know not at all. The master teacher if he has imbibed the spirit of the scientists will lead his pupils to the spirit of the poet, who apparently knew much about plants but being a scientist knew how much he did not know, when he wrote—

"Flower in the crannied wall,  
I pluck you out of the crannies,  
I hold you here, root and all in my hand,  
Little flower, but if I could understand  
What you are, root and all,  
I should know what God and Man is."

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## PUEBLOS LACKED VITAMINS.

The cliff dwellers who lived in the canyons of the southwest in prehistoric times never heard of vitamins and ultra-violet light, but a lack of these undreamed-of necessities was a main cause of their downfall, according to Dr. Walter Hough, of the Smithsonian Institution.

The decay of a race is one of the great problems of the world, Dr. Hough showed. The reasons for the passing of ancient cities and tribes may point a valuable and timely warning to modern civilizations.

A study of the food supply of the Pueblos was made in order to see whether it would account for their mysterious dwindling, beginning about 1000 A. D., long before the white man disturbed their country. Corn was their great food, and their diet was about 85 per cent. grain, the rest being meat and vegetables. The ration was adequate for sturdy adults but in winter the diet must have lacked in fat and vitamins and the children suffered, the scientist stated. Lack of fuel must have caused insanitary huddling in dark rooms of the pueblo in winter and this also weakened the babies.—*Science News-Letter.*

## BOTANY IN THE SECONDARY SCHOOL.

By N. L. Huff,
*University of Minnesota, Minneapolis.*

Should the study of Elementary Botany have an important place in the curriculum of the Secondary School, and, if so, why?

One of the principal methods of education is, and has always been to establish new points of contact between the life of the individual and the world in which he lives. This has a tendency to add to his knowledge, it enlarges his interests, thereby increasing pleasure, it increases his capacity for acquiring knowledge, it broadens his outlook upon the world, and it gives him a fuller a deeper, a more abundant life.

Botany offers a most excellent field for a new point of contact with Nature. Nothing in all the world is more absolutely essential for man's life than is the plant. It is the source of practically all his food, his clothing, his fuel, as well as of many other essential or useful products. The tiny green granule of the plant cell occupies a place unique in the cycle of life upon the earth. Nature has entrusted to the chloroplast, and to it alone, the power of arresting the sun's energy and with that energy of transforming elements of the inorganic world into organic material for building up the bodies of practically all living organisms. How it is accomplished we do not know, but it is a most wonderful process. In some mysterious way the little green bodies in the leaf capture the sun's rays and set them to work. Carbon, hydrogen, oxygen and certain mineral substances are combined into conplex organic compounds essential for the nutrition of all plant and animal life. And with this chemical change, that fleeting energy of the sun's ray is arrested and stored where at some future time it may be released to carry on the activities of a living organism, or to propel a locomotive across a continent.

Man has acquired a wonderful control of the resources of Nature, and in his laboratories has wrought miracles in breaking down compounds and rebuilding the elements into new and useful products. It seems highly doubtful, however, that food products built up in the laboratory could ever compete either in quality or cost of production with those formed by Nature. We may control Nature in her production of organic compounds, but we may never supersede her.

There was a time when the world's population was smaller than it is today, when the earth was covered with a luxuriant vegetation, when food and clothing marked the limit of man's

needs and desires so far as the plant world was concerned, and when these needs were satisfied by the native wild vegetation. But that time has passed. The world's population is rapidly increasing. Extensive areas have been cleared of their useful native vegetation in order to meet the needs of a growing population. Native plants have long since ceased to supply the demands for food, to say nothing of clothing, fuel, building materials and other essential products.

With the world's population constantly growing we are rapidly approaching the time when further increase will be limited by the capacity of available land areas to produce the necessary food. Every acre must in time increase its yield to the maximum. The world's meat supply depends upon wild and cultivated forage plants. A great many problems pertaining to crop plants, to our grazing lands, to our forests, can be dealt with only by those who understand the fundamental principles underlying the growth and development of plants. The world is and must continue to be fed from plant products, and the problem is becoming a more serious one every year.

Can Botany help to solve these problems? If plants were not affected by the conditions of their environment; if they did not possess the ability to respond wonderfully to certain external stimulae; to adjust themselves in order to better perform their life processes under a given set of conditions; if man were unable in any way to affect the conditions of their environment, or to change directly or indirectly their structures and their habits, then perhaps the study of Botany would have little to offer toward the solution of these problems. But when we consider the endless variety of fruits, vegetables, cereals and other cultivated plants which in the course of time have been developed from the all but worthless wild species, we may then appreciate the profound effect man may have in controlling and directing plant life. Every gardener who cultivates the soil confesses his belief in the effect of environment upon the plant, and every cultivated plant bears witness of man's influence upon plant structures. No living plant should be looked upon as a finished product. The future must see larger and better varieties than we have at the present time. Disease-resisting strains now unknown must be developed. We must have more hardy strains for the cold regions of the North and for the hot dry regions of the South and West.

In addition to the multitude of problems concerning common

field crops there are numerous others of vast importance connected with our forests which are being destroyed four times as fast as they are being replenished. Who can prevent this destruction?

But you say these are problems for the expert and how can Elementary Botany aid in their solution? With problems so fundamental to the welfare, the happiness, and the success of every individual of the Nation, we need CITIZENS who appreciate the facts, who understand the principles underlying plant growth, and who, because of this knowledge, are enabled to aid in countless ways in the production and control of our plant products; until we have such, many of these problems may never be solved.

It is true that we must have experts to aid in the solution of many such problems; true that one must have elementary training in his chosen field before becoming an expert. But the aim of Elementary Botany should not be the production of experts. It should be rather to contribute to one's general education. It should direct attention to the many useful plant products of every-day life in order to show how extensively plants contribute to our general welfare and happiness as well as to the absolute requirements of life. It should acquaint one with typical plants of the native vegetation and give one something of an insight into the fundamental life processes as illustrated by selected types. Life is perhaps the greatest mystery in the world. Man has a passionate desire to understand life. Many of the fundamental life processes can be studied easily and conveniently from plant materials, and these are particularly suited for use in secondary schools or even in the grades. A well-informed and enthusiastic teacher should never fail to arouse interest in the living plant. With an interested class and a subject of such vital importance to our welfare, the results of plant study are certain to have a real educational value.

Botany should have an important place in the training of the great mass of pupils who never go beyond the secondary schools. It should increase their powers of observation, and their capacity for acquiring knowledge. It should offer training in clear orderly thinking, in correlating facts, in organizing and systematizing knowledge, and in drawing logical conclusions. It should give them a greater knowledge of their environment and a broader view of life. It should broaden their interests, thereby increasing pleasure. The knowledge gained in the study of Botany should

find much usefulness in preparing for better citizenship; in aiding the Community, the State, and the Nation in the solution of important problems regarding the use of public lands, problems regarding agriculture, problems regarding forestry, and numerous other problems which can be worked out satisfactorily only by those who have an understanding of the fundamental principles underlying plant life. To summarize briefly, the great aim in the teaching of Elementary Botany should be "Preparation for Citizenship."

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## MOUND YIELDS 100 SKELETONS.

The excavation of an Indian mound located in the Oakwood Cemetery at Joliet, Illinois, has yielded 100 skeletons, in addition to various weapons, implements, and ornaments. The work was part of an archaeological survey of Illinois, under the direction of Dr. Fay-Cooper Cole of the University of Chicago, and W. M. Krogman, director in charge of field work.

An unusual feature of the exploration was the discovery of five cases in which mother and child had been buried together, the child clasped in the mother's arm in an eternal embrace. In each instance the age of the child was one year or less.

Of the 100 skeletons found, 22 were of persons under 2 years of age, 22 aged 2 to 16 years, 4 aged 16 to 60 years, and 10 over 60 years of age, while three were too fragmentary to classify. The preponderance of females among the adults was also noteworthy. There were 36 women, as against 12 men, a ratio of 3 to 1. The only explanation of this situation may be found in the fact that apparently no personage of great importance was buried in the mound, for the funeral gifts buried with the dead were very scant.

Almost without exception the young individuals were buried in an extended position, arms to side, and legs straight out. On the other hand, the adults were all buried in a flexed position, with arms drawn up to the face or chest, and legs drawn up so that the knees were upon the abdomen or chest.

The age of the mound is probably in the neighborhood of 500 to 1000 years. It is known that as soon as the white man came into contact with the Indian the trade material of the whites became objects of value and pride to the Indian and were buried with him. No objects of European manufacture were found in the mound, a fact which argues for the pre-historicity of the mound and its contents.

Associated with several burials of adult women were found ornaments of perforated shell serving as pendants. Around the neck of a child were found two "buttons" of shell, which had evidently been strung on a thong, as a necklace.

The presence of these ornaments, together with bone implements made of the foreleg of the deer, links this mound with the mounds and village material excavated at Channahon, some 12 miles to the west of Joliet, by George Langford of Joliet.

Mr. Krogman was assisted in the field by Robert Engberg, George Neumann, Robert Jones, Henri Denninger, Fred Eggan, all graduates of the University of Chicago, and Thorne Deuel, a graduate of Columbia University of New York.—*Science News-Letter.*

## TAKING STOCK IN CHEMISTRY CLASSES AT MID YEAR.

By J. O. Frank,

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Chemistry Teachers about to begin the second semester ought to take stock of past accomplishment and lay plans for the next semester. Every teacher ought to ask himself whether or not he is accomplishing the objectives of his course, and evaluate the prospects of accomplishing the year's objectives by the end of the second semester. It is often well to review and reconsider what we have set up as our objectives and perhaps to read thoughtfully the views of others as to what we ought to accomplish.

Let us assume that we are for the moment examining ourselves to see what we are accomplishing under the various items which we have set as objectives. Our questions would run, perhaps, about as follows:

*Instruction.*—Am I stuffing my pupils with facts—getting them to memorize a mass of subject matter, or am I getting them to understand broad general principles? Am I training them to do stunts and tricks or am I inducing them to think? Am I giving them tasks to do—busy work? Or am I inducing them to develop both old and new powers?

*Inspiration.*—Am I causing my students to find new interests and develop old ones with a burning zeal to go onward—or am I by lack of enthusiasm, lack of broad outlook, or because of a soured attitude, failing to help the students in my charge find new and worthwhile things to do? Am I overlooking chances to start the development of useful careers? Am I causing my students to become interested or am I merely trying to make my work interesting?

*Discipline.*—Am I teaching my students how to work—how to sacrifice to accomplish something worth while? Am I causing them to develop the ability to get along with others and to do an oversized piece of work when necessary? Am I teaching them to work without having something to explain—or failing to do that—to have the courage to stand on their merits?

*Power to Interpret.*—Am I teaching my students to think their way, evaluating evidence and reasoning from cause to effect? Am I training them to withhold judgment until the evidence is all in, and to cast prejudices and preconceived ideas aside—or am I running along in the traditional groove teaching blindly

in the same old way without a thought of checking accomplishment in terms of my real objectives?

*Exploration and Guidance.*—Am I conducting my work so as to find and develop any special abilities my students may have? Do I so deal with my students that I encourage them to try things which they may think they want to do—or do I discourage all extra work which is not a part of my schedule? Have I learned the special abilities of the students in my classes, and have I tried to encourage them and guide them into these fields? Or, is my work machine work, done with an eye on the clock at so much per day, and with no thought of the young lives which I have the opportunity to guide into better fields?

*Recreation.*—Am I bringing my students to enjoy chemistry and to take pride in its achievements? Am I inducing a real love for laboratory manipulations and an appreciation of the great accomplishments of research workers in this field? Will my students want to go on with chemistry when they have finished the beginning course with me?

Perhaps most chemistry teachers after asking themselves the above questions would get fairly satisfactory answers—would feel fairly certain of the first semester's work as already accomplished. Many experienced teachers however, will feel far less certain about the second semester.

## Second Semester Problems.

Experienced teachers have known for many years that there has been a marked difference in the success of the two semesters of first year chemistry. Most students begin the study of chemistry with considerable enthusiasm, for it is a field of mystery and has had a wonderful past achievement. Every beginning student has heard of this remarkable science and has read predictions of its possibilities and probable part in the future progress of society. Then, too, the first semester of chemistry offers something new, yet it deals with materials about which the student has always known something—perhaps just enough to excite interest and a desire to know more.

As a general rule, the subject matter presented and the many new experiences of the laboratory all open new and interesting fields and chemistry more than meets the students' expectations in the early months. As the work proceeds past the point where the fundamental laws and theories have had due attention and where the work settles down to almost routine procedure, the

student who has been used to new material and new manipulations at almost every stage, begins to feel a flagging interest. There are four or five points in first year chemistry where special effort must be taken to hold the interest of the student. Particularly during the second semester does the teacher have a difficult situation to meet. Here we still have a remnant of that early period when all science was taught by the tabloid method. In many schools, when a study of the metals is begun, the subject matter quickly becomes uninteresting because of the similarity of properties of the metals and because the laboratory work settles down to a monotonous repetition of experiments of a similar nature and the cataloguing of the properties of the metals. How often do students just finishing the first year say "never again" when asked whether or not they intend to go on with chemistry. The fact that large numbers of students begin with enthusiasm and finish with scepticism and lack of interest has been noted by many observers of high school chemistry.

## Some Solutions.

*"Make the work always a challenge of the student's ability—without making it discouragingly hard,"* is one of the axioms of able teachers. Give plenty of work—but never busy work. Make sure that everything, assigned the class, will accomplish some worthwhile end if properly carried out. When the work is done make the students feel that a new tool has been gained—and teach them how to use it.

Courses which have the subject matter so arranged or which are so taught as to fail to keep the student in an active learning situation, and which fail to provide increasingly difficult problems which will constantly offer a challenge to his ability to think and to manipulate, soon kill off all interest in chemistry and not only fail to accomplish the objectives of chemistry, but in addition, actually do the student harm. Such courses often drive from the study of chemistry, students who because of their demand for active learning, would make leaders in the profession.

Many attempts have been made in recent years to rearrange the subject matter of first year chemistry so as to make possible the treatment of progressively difficult material as the student grows in ability and understanding. Courses of this type have in some cases been successful with the subject matter of class room instruction, but total failures so far as the laboratory work was concerned. This was because no laboratory manipu-

lations were required which would induce additional skills and increasing *power to do*. In addition, few of these courses, which have broken away from the traditional order of treatment of subject matter have been free from severe criticism on other grounds. With all of its faults, the traditional order, when properly supported with laboratory work, seems to be the best yet found.

"*Introduce new fields of subject matter as fast as the students can understand and assimilate them,*" is another axiom worth consideration. Develop broad general principles, but make them practical by teaching the students how to apply them. First year chemistry is not a course for cataloguing a great number of specific facts—but a broadening course, one for culture—a course to develop appreciations. It is also a course which should find and develop special abilities and for this reason alone ought to cover all types of materials and give opportunity for all types of manipulations within the range of ability of beginning students.

### A Plea For Qualitative Analysis.

All too frequently both the subject matter and supporting laboratory work of second semester chemistry are not only devoid of variation and growing demands on ability and understanding, but there is also lacking sufficient breadth of experience and richness of material to give the subject its full exploration and guidance value. Many a brilliant student has failed to find an absorbing interest in chemistry until he, sometimes quite accidentally, has a chance to explore a little in the field of qualitative analysis. How many students who might have made fine chemists have been lost because they never had a chance to really explore the field? Isn't this the strongest argument for a more varied treatment of this work on the metals in the second semester of both high school and college chemistry? Isn't it an argument for a brief course in qualitative analysis? Isn't it true also that qualitative analysis offers opportunity for finding the aptitudes, abilities and interests, and that it also enables students to develop skills the possibilities of which might remain unsuspected throughout the ordinary course in first year chemistry?

No thorough course in qualitative analysis need be attempted. The purpose is not to produce able analysts, but to give an appreciation of, and a confidence in the practical manipulations

of chemistry, and to give the student an opportunity to exercise any ability in qualitative manipulation he may have. If only five or six weeks are available, much may be accomplished in this direction. Incidentally, the student will learn and retain much more about the metals and their salts than he will by the usual procedure—and at the end of the year he will have an unbounded interest in chemistry—rather than that "never again" attitude which often results with the traditional course. When ten to fifteen weeks of the second semester can be given to qualitative analysis, the fundamental operations and general ground work of the subject can be rather thoroughly treated, and the students left with a working understanding of the subject.

The writer believes that few teachers who have tried giving some qualitative analysis during the second semester, would consider returning to the old plan.

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## AQUEOUS INTOXICATION.

Intoxication by water is declared possible by Dr. Oliver Kamm of Detroit. Whether water is a harmless beverage depends upon the amount imbibed and the cellular constitution of the imbiber. The four glasses a day recommended by one of the insurance companies which has taken on the task of protecting the people's health may be too heavy drinking for a few individuals, while others may drink several gallons of water a day without slaking their abnormal thirst. Dr. Kamm has found that the amount of water demanded is dependent upon the activity of the posterior portion of the pituitary gland at the base of the brain. This little organ secretes two kinds of hormones, or regulators of the human system, so much alike that they have been called "the pituitary twins," but have recently been separated and are now employed in medicine for different purposes. They are distinguished as A and B, or on account of the traditional fondness of scientists for Greek, as alpha and beta. The beta secretion regulates the water supply. The portly person who persists in putting on weight in spite of cutting down his diet and drink may be suffering from an excessively active pituitary gland or from the undue sensitivity of his tissues to the secretion. He is called "fat" by his friends or his enemies, but he may be merely water-logged. On the other hand, the scrawny man, who remains lean however much food and water he takes, may have the opposite defect of pituitary action and be suffering from desiccation. This same beta hormone aids the frog in changing his skin color to suit his surroundings as a kind of camouflage. A frog in his light-colored costume turns dark on being treated with a minute dose of the hormone, because this expands the black cells in his skin. Dr. Kamm suggests that this secretion may save life in the case of extensive body burns, since the danger here is from the undue drying of the tissues.—*Science News-Letter.*

## NATURE'S GREAT AND SMALL AND MAN'S MEASUREMENT OF BOTH.

BY WM. T. SKILLING,
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### PART III. SPEED AND SPACE.

This is a day of great speed in communication and transportation. A radio listener of the Pacific Coast can hear words of a speaker in the national capital before they are heard by listeners on the outskirts of his audience. Air mail can be carried across the "Great American Desert" almost in the time it took a "Forty-Niner" to feed his oxen and get them yoked for the journey.

But man cannot equal nature in speed. Cosmic velocities make man's fastest rate a snail's pace. An army rifle ball goes half a mile a second. The earth carries all of us half that fast toward the east due to its daily rotation. This is slow compared with the rate of 18½ miles a second at which we are being carried around the sun by the earth's annual motion. Our innermost planet, Mercury, exceeds this velocity. As it curves around the fastest part of its track it is going 36 miles a second.

Such figures as these, though a bit staggering, must be credited for, as anyone may see, proof of their correctness lies in a simple arithmetical calculation.

Greater velocities differently measured are met with among the stars. The Doppler effect, so well known in the case of sound, furnishes a neat and reliable means of measuring radial motion (approach or recession) of the stars. A large part of the modern astronomer's work consists in photographing spectra of the stars. The lines in these spectra tell many things, but by their shift toward the red or violet end of the spectrum they reveal the secret of the stars' motion in the line of sight which would be impossible to find out in any other way.

To find how much the spectral lines shift one way or the other from their normal position a "comparison spectrum" of an artificial, and therefore stationary, light is photographed above and below the stellar spectrum. Then under the microscope of a "comparator" the tell tale shift is read and the velocity computed.

The velocities in the line of sight of about three thousand stars have already been measured, and their most

usual speeds are comparable to those of the planets, about five to twenty miles a second. Some are considerably faster than this, and the fastest one yet measured has a velocity of about 230 miles a second.

Meteors, which any night we may see darting across the sky, travel at a high rate of speed. If they did not do so their friction, or rather impact, against the atmosphere would not heat them to incandescence. It has been computed that a meteor or comet falling from practically an infinite distance toward the sun (and earth) would attain a velocity of 26 miles a second by the time it reaches the earth's orbit. Consequently if meteors meet the earth in a head on collision their velocity may be about 26 plus 18 miles a second. But if they run up behind in a rear end collision their speed is 26 minus 18. Meteors from different directions show different colors from reddish to white due to their speed and consequent friction.

A meteor striking the sun should have attained a velocity of 383 miles a second according to the laws of motion. The gravitational pull of the sun being known the velocity of a falling body is easily calculated.

The racing stables of the universe are located at the poles of the Milky Way. Here are quartered the spiral nebulae, which outrun all other heavenly bodies. It is difficult to get a spectrum of these distant and dim objects. The astronomer must sometimes sit at his telescope for five or six consecutive nights to give the required length of exposure to his plate. For this reason only some forty or fifty spirals have been measured but the average velocity of these is about 370 miles a second. The swiftest yet found travels at *nearly 1,100 miles a second.*

The spiral nebulae are not wholly without competition in the game at which they excel. A "new star" in the constellation Aquila has for several years attracted the attention of astronomers because of the great velocity at which nebulous matter rises from it.

This star became brilliant in 1918, due, apparently, to some explosive force which blew its surface layers out in all directions. The velocity of the shell thus blown out was more than 1,000 miles a second as measured by the spectroscope. The faint expanding haze has now given the star a diameter of about 20 seconds.

Incidentally the explosion that blew the cap off of this star occurred about the year A. D. 700, for its distance from us is in the neighborhood of 1,200 light years.

Is there any limit to velocity? Theory indicates that there is. Ether radiation such as light and radio waves travels, at about 186,000 miles a second, and all the energy in the physical universe could not propel any amount of matter, even an electron, with quite that speed. Matter has an automatic braking system set at that rate for its maximum speed. As velocity nears the speed of light the mass of even a small particle approaches infinity and refuses to be further hastened.

Electrons shot out of radium with a velocity of 99.8 per cent that of light are the fastest particles of matter known.

Scientists in their laboratories are tantalized by the fact that they cannot imitate the work of Nature's laboratory. Their best chance is with the vacuum tube. As a stone falls to the earth so electrons fall through a difference of potential. In a vacuum tube a difference of only one volt will impart to an electron a velocity of about 370 miles a second.

The Coolidge X-ray tubes used by medical men may be run up to 150,000 volts. It is the hammering upon the target by the rapid electrons in these tubes that produces the X-rays.

Recently Dr. W. D. Coolidge, of the General Electric Laboratories, has announced the completion of a "cascade" of three tubes placed end to end, so that as the electrons are passed on from one to another the driving force of each tube adds to their velocity.

He uses 300,000 volts on each tube, making a difference of potential of 900,000 volts through which the electrons must fall. This gives them a velocity of 175,000 miles per second, the greatest speed ever yet attained artificially.

The alluring hope is that such tubes improved may be made to produce the equivalent of the beta and gamma "rays" of radium. In such case a tube would have the advantage in intensity for it might be made to equal the action of a ton of radium.

In the light of recent experiments the space occupied by the known parts of the universe is the most stupendous

thing of all. Compared with the room occupied by such heavenly bodies as the sun, planets, and stars, the inter-stellar and inter-planetary empty space is almost incomparably great.

The only way to gain any appreciation of astronomical distances is by comparison, and that method is inadequate. If we start measuring by using the diameter of the earth as a yard stick we would have to lay it down sixty times to reach the moon. Now comparing the moon's distance with that of the sun the latter is found to be four hundred times as far away as the moon. The most distant planet is thirty times as far away as the sun, but the next leap through empty space takes us two hundred and seventy-two thousand times the sun's distance before we reach the nearest star.

It might well be imagined from the appearance of the sky that, having come to one star, we should find others close at its elbow, but such is not the case. Except for double stars, which are near enough to go around each other, the stars are as far apart as we are from the nearest one.

There is one more step to take through an empty abyss beyond the stars to the so-called "island universes," but first let us look at the methods of measurement.

With the introduction of telescopes into the study of astronomy it was found that a few of the stars were near enough so that with sufficient magnification they seem to slightly change position as viewed from opposite sides of the earth's orbit, at intervals of six months. The diameter of the earth's orbit thus may be used as a base line such as surveyors use in getting the distance to some inaccessible point, and the star's parallax found.

Surveyors use a base line of considerable length in comparison with the distance to be measured. But the shape of a triangle whose base is the earth's diameter and whose apex is at the nearest star would be the same shape as a triangle whose base is two feet long and whose length is fifty miles. The astronomer's task in measuring the distance to this star by getting its direction from opposite sides of the earth's orbit is similar to that of a surveyor shut in a room with only one window, two feet wide, and

told to measure the distance to an object fifty miles away by sighting upon it from opposite ends of the window sill.

And yet stars more than fifty times as far away as the nearest can be measured with some degree of accuracy. In the neighborhood of two thousand stars have been measured by the above trigonometric method. The shift of the star from side to side is not observed visually but upon photographic plates taken at intervals of nearly six months. The nearer stars shift with reference to the background of more distant stars.

Beyond a distance of about three hundred light years, that is, the distance light will travel in three hundred years, the trigonometric method described above fails completely. But other ways have opened for plumbing the depths of space still deeper.

A few years ago Dr. Adams of Mt. Wilson Observatory noticed that it was possible to tell the intrinsic brightness of stars by the character of certain lines in their spectra. Knowing the real brightness and the apparent brightness, which latter depends upon distance, the distance can be calculated.

It is as if a sailor should estimate his distance from a lighthouse by noting the distinctness of the light whose candle power is known to him.

One method of measurement more far reaching than any other was discovered through observations of Miss Leavitt of Harvard Observatory and developed by Dr. Shapley, the director. It consists in getting the real brightness of certain stars called Cepheid variables by simply observing the length of time required for the star to go through its period of change, which may be anywhere from a fraction of a day to about one hundred days. The longer the period the brighter the star, for some reason not well understood.

Dr. Edwin Hubble of Mt. Wilson Observatory succeeded in finding, by means of the one hundred-inch telescope, several Cepheid variable stars in those strange telescopic objects known as spiral nebulae. Finding their intrinsic brightness (from their periods) and comparing that with their apparent brightness, he was able to say that some of the nearer nebulae are a million light years away. Smaller and dimmer ones that he can see he estimates to be from

a million to a hundred and forty million light years from us.

These spiral nebulae are now called "island universes" for they are thought to resemble in form and size this swarm of some thirty billion stars which we call the stellar system. They are separated from the stellar system and from each other by vast reaches of emptiness.

The astronomer who goes beyond the stars in search of new "universes" to conquer reminds one of Kipling's "Tomlinson," who was carried far away until he

"Heard the roar of the Milky Way
Die down and drone and cease."

The light drifting in upon the earth tonight from these distant stars, coming at the rate of one hundred and eighty-six thousand miles a second, is fossil light. It shows what was taking place in the island universe at the time the light started, before there were men upon the earth to look at the stars.

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## STONE AGE JAWBONES ON ISLANDERS.

Massive jawbones, resembling in many details of structure the jaw of the ancient Heidelberg Man, has been found by Prof. A. N. Burkitt of Sydney University in a collection of modern human remains from the South Sea island of New Caledonia. He reports his researches in the British scientific journal, *Nature*.

The discovery of the Australian anthropologist suggests the possibility of a revolutionary change in our assumptions concerning the kind of a person *Homo Heidelbergensis* was. It has always been taken for granted that he was a pronounced lowbrow. Though no skull of his race has been discovered, and a single jawbone is the only Heidelberg relic ever turned up, this jawbone is of such brutish proportions that the assumption has always been that the rest of his head must have been shaped to match it, and that in particular he had a low and sloping forehead and a brain notably smaller than that of modern man.

The jawbones examined by Prof. Burkitt are more advanced in structure than the Heidelberg jaw in some respects, notably in having more of a chin, but they are decidedly "Heidelbergian" in their general depth and massiveness and especially in the width and configuration of the ramus, or angle where the jaw fits into the cheek. But the natives of New Caledonia are not lowbrows; even though they are savages their skulls are "modern," and their brains are just about as large as those of contemporary Europeans.

This leaves us with the possibility, disquieting to current anthropological assumptions, that the massive-jawed Heidelberg man did not necessarily have a gorilline cranium. And nothing short of the discovery of a Heidelberg skull can really settle the matter.—*Science News-Letter.*

## THE DEMONS OF ELEMENTARY MATHEMATICS.

By Wilbur A. Coit,
*Broadway High School, Seattle, Wash.*

To the observing teacher of Algebra, whether in High School or University, it is evident that a majority of the pupils have difficulty in mastering certain topics regardless of the book used as a text. Is it not possible that there are a few very elementary yet fundamental concepts and skills which, if completely mastered, would result in a marked improvement in the mathematics and allied subjects at every level?

In the discussion that follows will be found a statement of the methods used and results obtained in a preliminary study of the difficulties in mathematics. It is but the beginning of a systematic effort to discover, if possible, whether or not "Demons" exist which account for a large per cent of the failures.

It is hoped that a by-product of this effort will be the bringing together of the best methods and devices used by the teachers of mathematics in the Seattle High Schools. If this is accomplished, the material will be classified according to topic and sub-topic in loose-leaf form and each teacher supplied with the result. It will thus be possible to add new material as it is collected.

The investigations were first carried on last year in one high school. The tasks given in the tests, though elementary, brought to light a surprising lack of mastery not only among 9B students, but also among those of higher levels. It therefore seemed best to start with the elementary work of the grades immediately preceding High School as well as that of the first year in High School.

The tasks of this test appear at the top of Plates I and II. The graphs on all plates give the percentage of failures on each of the questions. The tests were carried on in four high schools. Each teacher thoroughly understood the necessity of uniformity, both in the giving and the grading of the papers. To this end, answers to all questions were furnished and the results were all checked and often rechecked to assure as little error as possible.

Plate I graphs the percentages of failure for each of four schools in Seattle, Washington, on each of the forty ques-

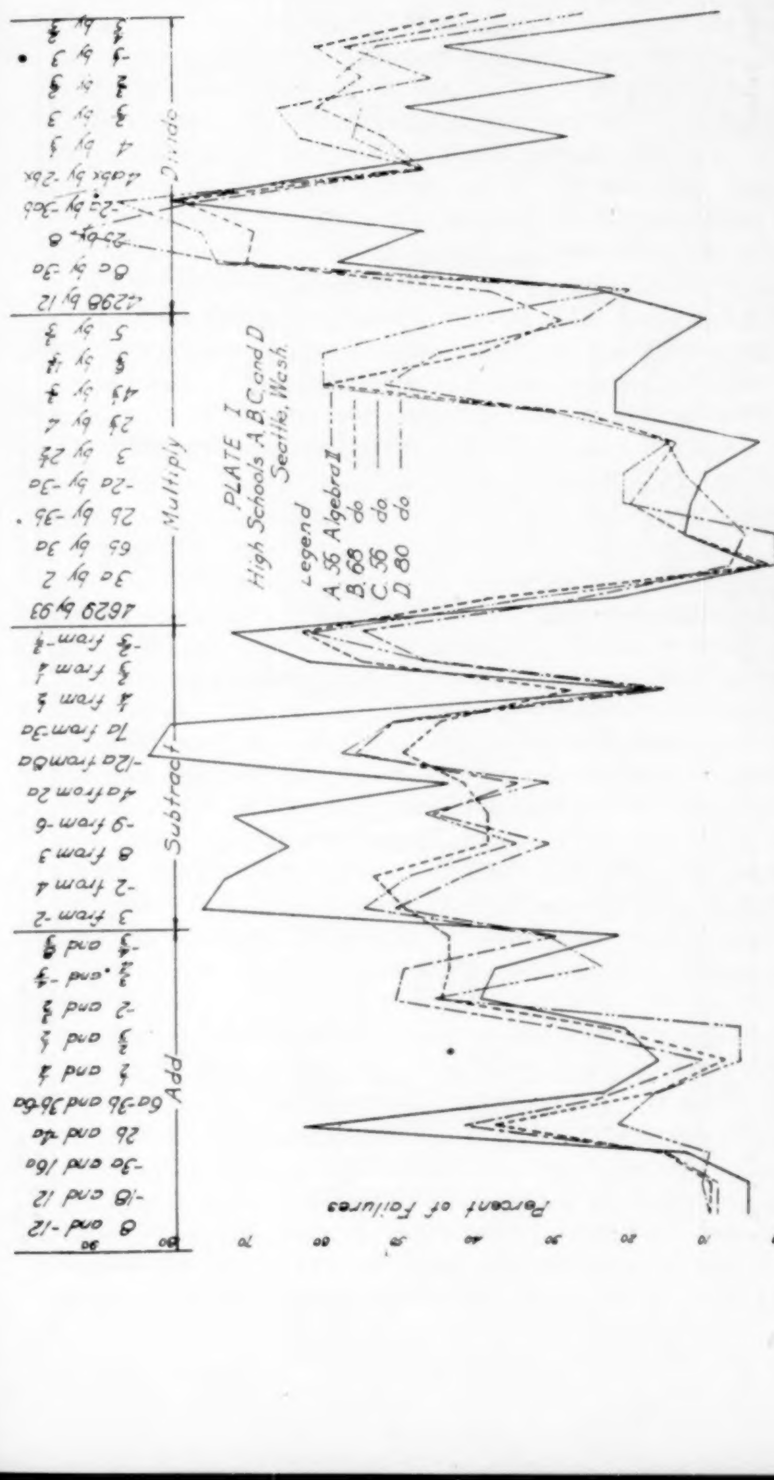


PLATE I.

The test at the top of the plate was given to groups of algebra II students in four different high schools, denoted as A, B, C and D, at Seattle, Wash. The four graphs give the percentage of error on the various questions for each high school. Note the uniformity in the positions of the "highs" and "lows" for the four schools, and compare with Plate II.

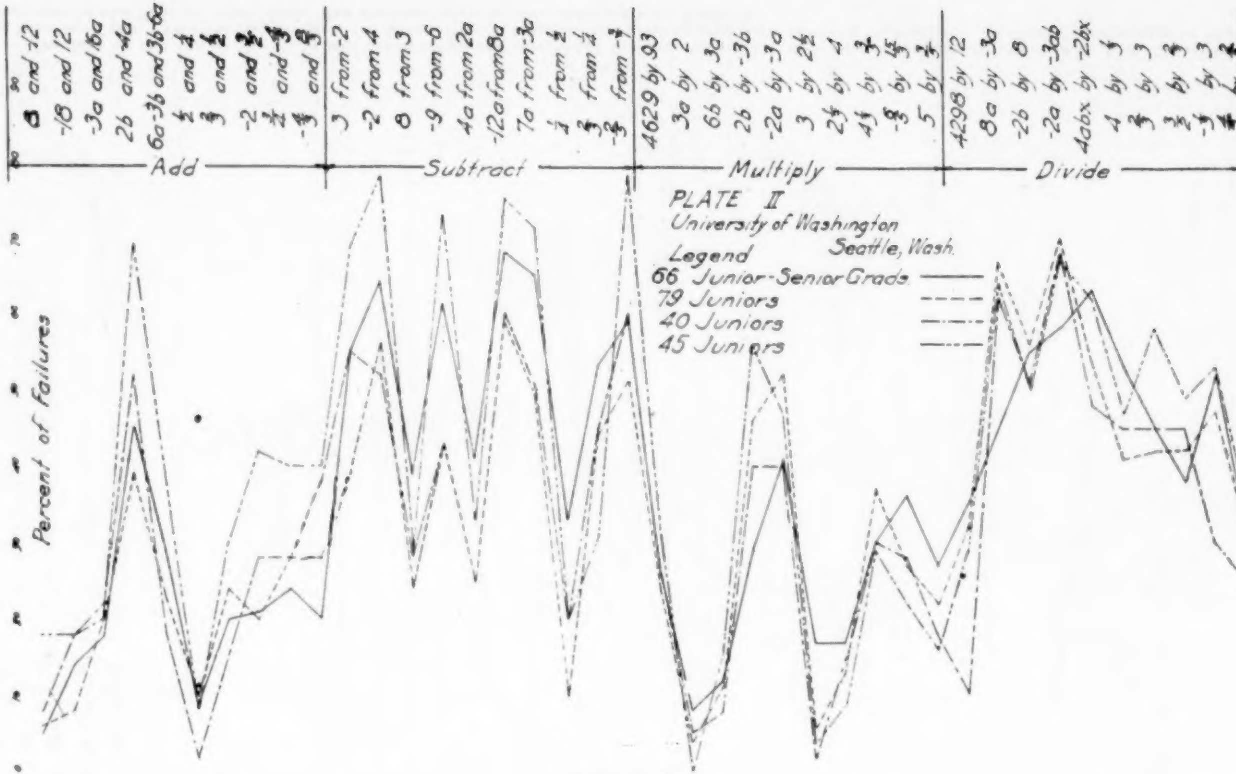


PLATE II.

**The test given at the top of the plate is the same as that on Plate I and was given to four groups of students in the Department of Education at the University of Washington, Seattle. The four graphs indicate the percentage of failures on the different questions by each group. Note how closely the trend of the graphs follow each other, and compare with Plate I.**

tions. There are at least two striking features on this plate. First, the high percentage of failures on many of the questions, although each of them is comparatively simple. Second, the close similarity in the trend of the graphs for the different schools. For example, the percentage of failures for each school was comparatively low on the first three questions in addition, but on the fourth question, adding 2b and 4a, the failures range from 21 to 62 per cent. On the sixth question, adding $\frac{1}{2}$ and $\frac{1}{4}$, the range is only 5 to 16 per cent for all schools.

On Plate II are graphed the results of the same test given to four groups of upper class students at the University of Washington. The similarity of the two plates is evident at a glance. With but four exceptions the high and low frequencies appear at approximately the same questions.

It seems rather remarkable that 260 High School students and 230 University upper classmen and graduates show so uniform a tendency towards poor work on the same questions, especially when one considers the simplicity of many, if not all of these questions. Practically all of them should be answered correctly by a good student in grade 8A and most of the remaining by a 9B student. The fact that in every-day life one seldom runs across many of the type of questions used does not seem relevant. Not only had the four fundamental operations considered been taught to the majority of the four hundred and ninety pupils who took the test, but also many examples similar to, if not identical with those asked, had doubtless been worked out by them. How did it happen that so many in a select group such as University juniors, seniors, and post-graduates failed on very simple examples involving very elementary operations?

Although the diagnostic work on the test will take much time and little so far has been done, yet the few results obtained seem significant. For example, out of 180 pupils in Algebra II, 61 failed on the question "Subtract 3 from $-2$" and had two or less of the other ten questions in subtraction correct. Of the 61 that failed in subtracting 3 from $-2$, 43 had correct "Subtract $\frac{1}{4}$ from $\frac{1}{2}$." Another interesting fact is that of these 180 students 27 failed on all questions in subtraction except "Subtract $\frac{1}{4}$ from $\frac{1}{2}$."

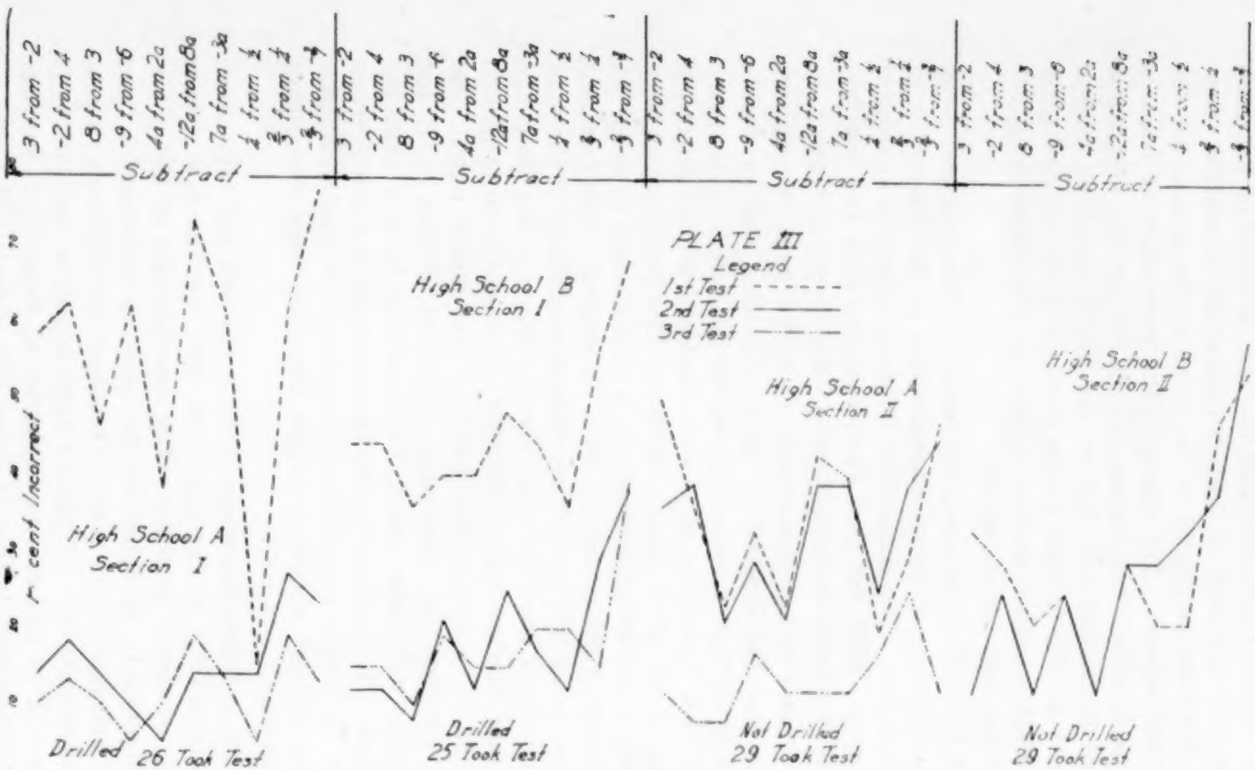


PLATE III.

The test shown at the top of the plate was given to groups in High Schools A and B at Seattle, Wash. The percentage of failures on each question for the first test is graphed by a dash line. The full line graphs the result for the same test given after one hundred minutes of drill covering ten days. The dash two dots line graphs the results for the same test given two months after the second test. There was no drill between the second and third tests. Section II, High School B, was not given the third test.

Moreover, in the majority of cases the false results given were obtained by straight addition, 69 giving the answer as plus 1. If it were not for the one question correct, namely, "Subtract ¼ from ½," one might conclude that, due to carelessness, those taking the test thought the questions were still under the heading "Add." Again, of the 61 who failed in subtracting "3 from —2" there were 19 that had ""Subtract —2/5 from —3/7" correct, —a problem naturally considered far more difficult than "3 from —2."

In pursuing the investigations, request was made that subtraction be first considered. The answers to the tasks involving subtraction were again gone over and, although little time could be given to the work, there was discovered ample evidence to show conclusively that there was a widespread lack of knowledge of the meaning of subtraction, and of the fundamental concepts connected with the operation. Moreover, conversations with various teachers brought to light the fact that there had been no attempt in teaching the subject to present the various forms in which subtraction could appear. Instructions were therefore sent each of the cooperating teachers asking them to drill the students for ten minutes a day for ten consecutive days on a prepared set of examples. No other examples were to be used.

As many minutes as was necessary were first to be devoted to presenting to the students seven forms in which subtraction might appear. One-half of the sections in the various high schools that had taken the first test were to be drilled and at the close of the ten days work all sections were to have a retest in which the same questions used in the first test were to be employed. This was done after a lapse of two months with no drill on subtraction, they were given a second retest. The results of the first and second retests will be found on Plates III and IV.

The graphs give the percentage of failures of each section on each of the ten questions for the different tests. For example, in Section I school B, 41 per cent of the 25 pupils failed on the first question in subtraction. After 100 minutes of drill, covering ten days, only 15 per cent failed on the same question in the first retest. In the second retest, given after a lapse of two months, with no drill, 12

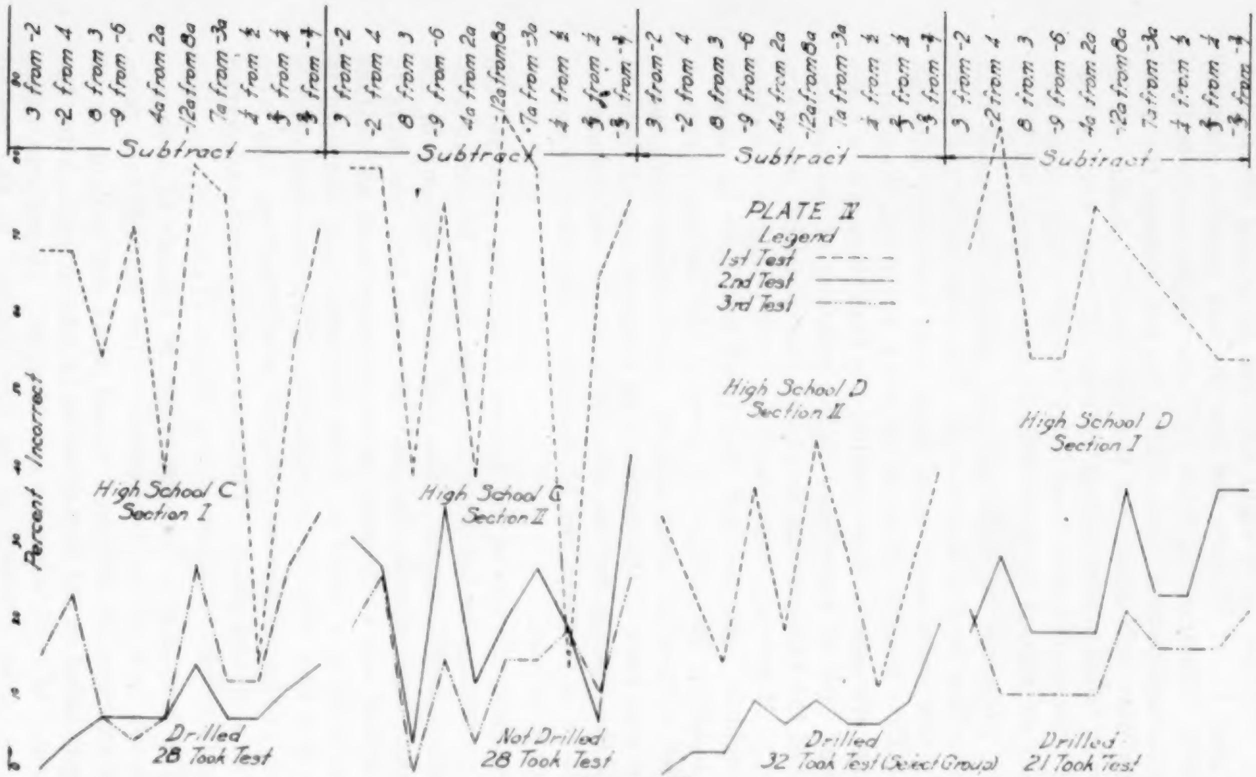


PLATE IV

**The test at the top of the plate was given to groups in High Schools C and D at Seattle, Wash. The percentage of failures on each question for the first test is graphed by a dash line. The full line graph gives the results for the same test after one hundred minutes of drill covering ten days. The dash two dots line graphs the results for the same test two months after the second test with no drill between. Section II, High School D, was not given the third test.**

per cent failed on the same question. It is evident that the effects of the drill persisted for the period of two months. The undrilled section in the same school composed of 29 pupils did better work on the test than Section I, but, as might be expected, showed but little improvement on the first retest. They were not given the second retest. Section I of school A did not do as well as Section I of school B in the first test, but effects of the drill resulted in an improvement so marked that they did better work on the first retest than Section I of school B. Although Section II in high school A was not drilled, there was considerable improvement on the second retest. Turning to Plate IV, we find both sections of school D did poor work on the first test. On the retest there was great improvement not only in the drilled, but also the undrilled section. The improvement of the drilled section was much more marked than that of the undrilled.

Was this improvement in the undrilled section due to the fact that the teacher unconsciously emphasized the methods of subtraction after the first test? Was the section composed of many who were ashamed of their first test and of their own accord reviewed subtraction? Was there a natural improvement due to excellent teaching? It would be difficult if not impossible to decide the cause or causes, but possibly the results of the second retest shed light on the question. Here we find the undrilled section not only holding what had been learned, but even showing still further improvement, whereas the drilled section did not do as well as on their first retest.

Section II of high school D showed considerable improvement on the first retest in spite of having had no drill. This was a segregated group of pupils of marked ability. They had no second retest. Section I of the same school not only showed marked improvement after the drill, but showed the greatest improvement of all sections on the second retest.

To summarize:

It is evident that the drill as given resulted in marked improvement and that this persisted over a period of two months.

Not only is there a closeness of similarity in the curves showing the percentage of mistakes of the different sec-

tions on each of the forty questions, but also a closeness of similarity of results from the drill given.

The 260 high school students made 3,798 mistakes on the 40 questions or an average of 95 mistakes per question. The 230 University students made 3,245 mistakes with an average of 81 mistakes per question. For the high school students, the total number of mistakes on questions 1, 2, 4, 6, 7, and 9 of subtraction and questions 2, 3, 4, 5, 7, and 9 in division (a total of 12 out of 40 questions) was 1,851 or about 50% of the total number of mistakes on all 40 questions. For the University students, the total was 1,557 or about 48% of the total number of mistakes.

Although the investigations are barely under way, the results seem to indicate that there are "Demons" in mathematics that will be brought to light by the methods employed.

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## NEW METAL CUTS GLASS.

A new metal so hard that it will bore smooth holes in concrete, or cut screw threads in a glass rod, was exhibited for the first time at the convention of the American Society for Steel Treating in Philadelphia. With present-day tools such feats are difficult or even impossible.

The new material, known as carboloy, and consisting of tungsten carbide, a compound of tungsten and carbon, and cobalt, a metal like nickel, is the invention of Dr. Samuel L. Hoyt, of the research laboratory of the General Electric Co. It is so hard that it will cut glass like a diamond, and will even scratch a sapphire, which is next below the diamond in the scale of hardness. Ordinary steel tools are quickly worn down when held against an emery wheel, but the new metal itself wears down the wheel.

One important use for it described by Dr. Hoyt is in the cutting of materials containing metal inserts, as the fiber and metal gears used in automobiles to give quietness. Cutters of cobalt and chromium alloy, the best previously used for this work, require sharpening after machining 150 parts, but carboloy tools have cut 11,000 before they required redressing.—*Science News-Letter.*

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The total cost of public elementary and high schools in the United States in 1903 was $251,457,625; by 1913 this amount had doubled, being $521,546,375; by 1920 it had doubled again, $1,036,151,209; and in 1926 again doubled to $2,026,308,190. This doubling process promises not to continue indefinitely since the increase in expenditures has been slowing down during the past two or three years. The cost per pupil in average daily attendance was $95.17 in 1924, $98.45 in 1925, and $102.05 in 1926. Expenditures per capita of population for these years are $16.25, $17.15, and $17.50.—*Department of Interior.*

# ON THE CONCEPTS OF MASS AND FORCE.

BY J. RUD NIELSEN,[1]

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The concepts of *mass* and *force* are of fundamental importance in Physical Science. They are, however, rather difficult concepts, and their definitions are given very unsatisfactorily in most text-books, not only in elementary books but even in many advanced books on mechanics. The difficulty is due not only to the fact that the fundamental laws of dynamics do not lend themselves well to demonstration by simple experiments, but also to the fact that the two concepts of mass and force have not been developed independently. There is at least historical and pedagogical truth in the statement of A. N. Whitehead that "we obtain our knowledge of forces by having some theory about masses, and our knowledge about masses by having some theory about forces."[2]

The concept of force has its origin in our sensations of push or pull, and was first developed as a scientific concept in *statics* or the theory of the equilibrium of bodies. There it is defined by the statement that a body $A$ resting in contact with another body $B$ is said to exert a force on $B$, if the removal of $A$ will result in a change of position of $B$. Now, it is a matter of experience that the same effect on $B$ can always be secured either by the application of a suitable system of strings, pulleys and weights or by the use of elastic springs, and this fact provides the statical methods for measuring force. Thus the force of $A$ upon $B$ is measured either by the weight which must be applied to keep $B$ in equilibrium after the removal of $A$, or by the stretching or shortening of a spring used for the same purpose. The spring or the string used in the measurement must have a definite direction, and thus force it to be regarded as a vector quantity. It is to be noted that the static idea of force is quite independent of any notion of mass.

In the science of *dynamics*, which has as its purpose the description of the motion of bodies, the concept of force becomes gener-

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[2]A. N. Whitehead, An Enquiry Concerning the Principles of Natural Knowledge, Cambridge University Press, 1919; p. 18.

alized, and the idea of mass is introduced. To have realized the necessity for a concept of mass, different from weight, and to have given us a dynamical concept of force, are among Newton's greatest achievements. Newton defined mass as "quantity of matter," as obtained by multiplying density by volume. This, of course, is really not a definition of mass but rather of "quantity of matter" or density. The real definition of mass is only implicitly given in Newton's works. In fact, Newton did not define the concepts of mass and force as well as he applied them. That is quite natural. It would indeed have been remarkable if the marvelous development of physics since Newton's time had called for no modification of his statement of the fundamental principles of dynamics. The peculiar thing is that more than two hundred and fifty years should pass before a constructive criticism was given of Newton's definitions of mass and force and of his three laws of motion, and that even today the effect of this criticism is hardly noticeable in the textbooks.

A great number of textbooks still define mass as "quantity of matter." One widely used textbook on analytical mechanics states simply that mass is "measured matter." Such definitions are based on the important facts that the mass of a body is the sum of the masses of its parts and that it remains constant as long as no part of the body is removed. Other books define mass in terms of the weights found by means of a beam balance, or as the ratio of the weight measured by a spring balance to the acceleration of gravity. These definitions are based on the proportionality of mass and weight, a fact which, however important and remarkable it may be, has nothing to do directly with the fundamental laws of dynamics. Hence such textbooks do not define mass as a dynamical concept, but merely give important methods for measuring it. Similarly, such books give, in general, no dynamical definition of force but carry the concept of force over from statics without any discussion of the difficulties involved, or else define force as the "cause of a change of motion." The latter definition is a very common one, but in the first place it is not quantitative and in the second place it is metaphysical in presupposing the idea of "efficient causation" which has no place in Physical Science.

Before I give what I consider the most satisfactory definitions of mass and force, let me say that one of the best treatments of the subject that I have found so far in an elementary textbook is that contained for instance in Duff's "Physics for Students of

Science and Engineering."[3] A preliminary idea of force is given first; then the ratio of the masses of two particles is defined as the inverse ratio of the accelerations which equal forces will impart to the particles, and, finally, force is *defined* as the product of mass and acceleration. The only objection to this procedure is that it presupposes the possibility of defining equality of forces acting on different bodies. Now the only methods of comparing forces, before the concept of mass is introduced, depend either on gravitation or on elastic properties of certain bodies, which means that this way of defining the dynamical concepts of mass and force contains a non-dynamical element.

A purely dynamical definition of mass was first given by Ernst Mach in 1867. His paper was rejected by the "Annalen der Physik" but was published a year later in a journal of less repute. A similar definition was given by Kirchhoff in the first volume of his famous "Vorlesungen ueber Mathematische Physik" which appeared in 1874. Mach later elaborated his criticism of the traditional treatment of the laws of motion in his book "Die Mechanik in ihrer Entwickelung" which was published in 1883. Karl Pearson in his "Grammar of Science," which appeared in 1892, arrived independently at conclusions similar to those of Mach. This new treatment of the fundamental concepts and laws of mechanics is adopted in such works as Boltzmann's "Vorlesungen ueber die Prinzipe der Mechanik" and Whittaker's "Analytical Dynamics," but other authors such as Haas in his "Introduction to Theoretical Physics" and Jeans in his "Theoretical Mechanics" follow more or less closely the older tradition.

The dynamical definitions of mass and force may be given briefly as follows. Let us first consider the motion of two material particles far removed from all other bodies. We may think, for example, of a double star for which the distance between the two bodies is large compared with their diameters. It is found (e. g. by astronomical observations) that the acceleration of either particle is always directed towards the other particle. Observations further teach us that the magnitudes of the accelerations depend solely upon the distance between the particles, while the ratio between the two accelerations is found to be always the same, no matter what the positions and motions of the particles are.

When we have three particles $P_1$, $P_2$, $P_3$, matters are more

[3] Sixth edition, P. Blakiston's Son & Co., Philadelphia, 1926.

complicated. Let the acceleration of $P_1$ be resolved into a component $a_{12}$ in the direction of the line joining $P_1$ and $P_2$ and a component $a_{13}$ in the direction of the line joining $P_1$ and $P_3$. We find then, from observation, that the magnitude of $a_{12}$ depends on the distance $r_{12}$ between $P_1$ and $P_2$ and is quite independent of the position of $P_3$. In the same manner $a_{13}$ is a function only of $r_{13}$, the distance between $P_1$ and $P_3$. Similar results hold for the components $a_{21}$, $a_{23}$, $a_{31}$, and $a_{32}$ of the accelerations of $P_2$ and $P_3$. Furthermore, it is found by observation that the following relations hold:

$$(1) \qquad \frac{a_{12}}{a_{21}} = -C_{12}, \quad \frac{a_{13}}{a_{31}} = -C_{13}, \quad \frac{a_{23}}{a_{32}} = -C_{23},$$

where $C_{12}$, $C_{13}$, and $C_{23}$ are positive constants independent of the positions or motions of the particles. These constants, however, are not independent, for it is found that:

$$(2) \qquad C_{23} = \frac{C_{13}}{C_{12}}.$$

If we put

$$(3) \qquad C_{12} = \frac{m_2}{m_1}, \quad C_{13} = \frac{m_3}{m_1},$$

where $m_1$, $m_2$ and $m_3$ are new constants, any one of which may be chosen arbitrarily, we have from Eq. (2) that $C_{23} = \frac{m_3}{m_2}$, and Eq. (1) may then be written in the more symmetrical form:

$$(4) \qquad m_1 a_{12} = -m_2 a_{21}; \; m_1 a_{13} = -m_3 a_{31}; \; m_2 a_{23} = -m_3 a_{32}$$

In the case of a larger number $n$ of particles $P_1$, $P_2$, $P_3 \ldots$, $P_n$, the acceleration of any particle $P_h$ may always be resolved into $n-1$ components $a_{hk}$ directed towards each of the $n-1$ other particles in such a manner that $a_{hk}$ is a function only of the distance $r_{hk}$ between $P_h$ and $P_k$. The accelerations $a_{hk}$ are found to satisfy a set of equations of the following type:

$$(5) \qquad m_h a_{hk} = -m_k a_{kh} = f_{hk}(r_{hk}), \quad \left.\begin{matrix} h \\ k \end{matrix}\right\} = 1, 2, 3, \ldots, n,$$

where $m_1$, $m_2$, $m_3$, ... $m_h$ are constants, any one of which may be chosen arbitrarily, and $f_{hk}(r_{hk})$ signifies a function of $r_{hk}$. *The constant $m_h$ is called the mass of $P_h$, while the product $m_h a_{hk}$ or*

$f_{hk}(r_{hk})$ *is called the force exerted by* $P_k$ *upon* $P_h$. These definitions of mass and force are based on purely dynamical observations. The extension of these concepts from particle dynamics to the dynamics of rigid or deformable bodies involves no difficulty.

The accelerations $a_{hk}$ are vectors; hence force is a vector. As the well-known rule for vector addition applies to accelerations, it applies to forces as well. Thus the Law of the Parallelogram of Forces follows immediately from our definition of force. The Law of Action and Reaction is explicitly contained in Eqns. (5), since $m_k a_{kh}$ is the force exerted by $P_h$ upon $P_k$, and $m_h a_{hk}$ the force exerted by $P_k$ upon $P_h$. If Eqns. (5) be taken together with the important empirical fact that the function $f_{hk}$ vanishes as $r_{hk}$ approaches infinity, it is seen that a body far removed from all other bodies will have no acceleration, i. e. will move with constant velocity. We thus obtain the Principle of Inertia or Newton's First Law of Motion.[4]

The definition of force as the product of mass and acceleration has been criticized by various writers. Whitehead, for example, makes the following statement: "The difficulty to be faced with this definition is that the familiar equation of elementary dynamics, namely, $ma=f$, now becomes $ma=ma$. It is not easy to understand how an important science can issue from such premises."[5] To this argument we simply remark that no claim has been made that anything should follow merely from the definition of force. The concept of mass is based on the relations $m_h a_{hk} = -m_k a_{kh}$, and the justification for the introduction of a special name for the product of mass and acceleration lies in the discovery that this product is a function of the distance between the particles, as expressed in the second part of Eqns. (5). Perhaps it would have been a little more satisfactory to define force not simply as the product of mass and acceleration but rather as the function of the distance between the particles to which this product is equal.

It should be pointed out that the dynamical concept of force is free from the anthropomorphic element which attaches to the

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[4]The question as to what frame of reference should be used in defining the accelerations has not been raised in the above discussion. For Newton this question did not exist, as he believed in an absolute space as well as in an absolute time. We have tacitly assumed that the coordinate system used belongs to the class called *inertial systems*. If another coordinate system had been used, the empirical results could not have been stated in so simple a form.

We have considered the concepts of mass and force only from the point of view of classical mechanics. In the Theory of Relativity the concepts are redefined, and mass is made synonymous with energy. The modern sub-atomic physics seems to call for further modification. A discussion of these much more difficult matters is beyond the scope of the present paper.

[5]A. N. Whitehead: loc. cit. p. 10. The symbols for force and acceleration are changed here.

statical concept. The dynamical concept is, of course, a generalization of the static concept, since all statical phenomena, as is easily shown, can be described by the laws of dynamics. While the old statical concept of force thus has been replaced by the more comprehensive dynamical one, it may be good pedagogy to make use of the statical concept of force in elementary teaching to prepare the way for the more abstract dynamical concept. Mass, on the other hand, is a purely dynamical concept, and should be defined as such.

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## HELPING THE TEACHER OF PHYSICS.

By Geo. W. Gorrell *University of Denver, Denver, Colo.*

In my earlier work as an instructor I had some experience in teaching physics. I found that students were often halted in their progress by their inability to apply some simple mathematical principles to conditions new to them. These principles were not numerous but of frequent occurrence.

In such equations as the following, it is often necessary to solve for values not explicitly given:

$$T = 2\pi \sqrt{\frac{l}{g}}, \quad n = \frac{1}{2l} \sqrt{\frac{T}{m}}.$$

In connection with the first formula given above, the problem in the laboratory is usually to find $g$. But many students who have done creditable work in algebra appear quite helpless when called upon to solve this equation for $g$. This fact suggests more careful attention to the solution of literal equations in algebra. And a number of them should be given which do not contain the conventional $x$ and $y$.

Two of the trigonometric functions, the sine and the cosine, are very frequently used in physics. In fact, inasmuch as vector quantities are constantly coming up, it is important that the student be able to think quickly and accurately in terms of the sine and cosine components. I believe the average student is handicapped in this particular because of the way in which his first month is spent in plane trigonometry. The definitions of the trigonometric functions are usually given in terms of the sides of a right triangle and numerous problems are then solved in application of these functions. A very lasting impression seems to be made upon the student's mind that trigonometry has to do only with the solution of triangles.

Ideas will be clarified by a full and careful discussion of the subject of projections of lines upon north and south lines, and then upon the rectangular co-ordinate axes.

An excellent illustration for discussion is the running by a surveyor of a line somewhat west of north. It is easily seen by the student that the surveyor may wish to know the departure of the line from a north and south line through the starting point, and also from an east and west line through this point. If a little preliminary work has been done in the elements of co-ordinate geometry, the student readily gets the idea that the projection upon the y-axis is positive in this illustration, and the projection upon the x-axis is negative. If the student is taught to tie up his trigonometry with his co-ordinate geometry, he is thereby freed from some of the difficulties in his way.

# A COMPARATIVE STUDY OF THE EFFECTIVENESS OF MODELS, CHARTS AND TEACHER'S DRAWINGS IN THE TEACHING OF PLANT STRUCTURES.

BY DOROTHY E. HUEBNER,

*Fenger High School, Chicago, Ill.*

It is the purpose of this investigation to determine the relative effectiveness of the model, chart and teacher's drawing as aids to the teaching of botanical structures in high school classes.

The following investigation was carried on in the botany department of Central High School, Grand Rapids, Michigan, in the Spring Semester of 1926.

Four classes, two in advanced and two in beginning botany, were selected for the study. All the classes had their laboratory periods on the same day, and the classes followed each other consecutively through the day. The single period recitation classes were so planned that the two like classes met at consecutive hours. This schedule of time made it possible to give the same test questions to both classes, since there was only a three minute intermission between classes to permit passing.

The course of laboratory exercises was so planned that each pair of classes would receive an equal amount of instruction by each of the three visual aids, namely models, charts and teacher's drawings by the teacher. The advanced classed each undertook five exercises using models as aids, five exercises using charts as aids and five exercises using teacher's drawings as aids. The beginning classes each did four exercises by each of the three methods. As far as possible the same class never received instruction by the same method twice in succession. In other words the three methods were rotated throughout the semester, so that not all the very complicated as contrasted with the simple structures would be taught by one method; and also so that the pupils would not learn to interpret any one of the particular types of illustrative materials better than any other because of more frequent use of that method.

At the beginning of each laboratory period the teacher introduced the plant structure to be studied that day by means of a lecture demonstration, using as a visual aid to the understanding of its structure either a model, a chart, or a diagrammatic blackboard drawing which had been carefully drawn previous to the class time. This explanation was given in exactly the same manner to each of the two classes having the same exercise, the only difference being in the type of demonstrational material

used. The teacher was careful to emphasize all the important structural points of the organism. After the explanation the pupils were given a limited period of time in which they were privileged to examine the model, chart or teacher's drawing and ask any question regarding the structure. Then the visual aid was removed from sight and the pupils were required to examine the actual plant materials for details, described and seen during the teacher's explanation and demonstration. Drawings and notes were kept as records of laboratory work. Ten minutes before the end of the class hour, all note books, materials and

TABLE I—SUMMARY OF THE AVERAGES ON IMMEDIATE TESTS BY EACH OF THE METHODS.

| Pupil | Model | Chart | Teacher's Drawing | Pupil | Model | Chart | Teacher's Drawing |
|---|---|---|---|---|---|---|---|
| 1 | 78.0 | 75.4 | 71.6 | 40 | 85.0 | 85.0 | 92.5 |
| 2 | 69.0 | 62.0 | 71.4 | 41 | 76.2 | 92.5 | 81.2 |
| 3* | 74.0 | 67.6 | 74.8 | 42 | 93.7 | 87.5 | 97.5 |
| 4 | 89.0 | 94.0 | 92.0 | 43 | 67.5 | 58.7 | 75.0 |
| 5* | 81.0 | 75.0 | 72.0 | 44 | 63.7 | 72.5 | 71.2 |
| 6* | 83.0 | 57.4 | 74.0 | 45 | 78.7 | 78.7 | 77.5 |
| 7 | 91.0 | 96.0 | 94.0 | 46 | 67.5 | 70.0 | 61.2 |
| 8 | 97.0 | 94.0 | 93.0 | 47* | 67.5 | 61.2 | 58.7 |
| 9* | 82.0 | 85.0 | 81.0 | 48* | 71.2 | 75.0 | 82.5 |
| 10* | 84.0 | 84.6 | 91.4 | 49* | 85.0 | 73.7 | 88.7 |
| 11* | 92.0 | 86.0 | 91.0 | 50 | 78.7 | 56.2 | 80.0 |
| 12 | 62.0 | 51.8 | 60.0 | 51 | 100.0 | 86.2 | 92.5 |
| 13* | 79.0 | 65.0 | 75.4 | 52* | 83.7 | 87.5 | 77.5 |
| 14 | 79.0 | 83.0 | 78.0 | 53* | 80.0 | 60.0 | 88.7 |
| 15 | 91.0 | 92.0 | 95.0 | 54* | 51.2 | 52.5 | 75.0 |
| 16 | 84.0 | 83.0 | 91.0 | 55 | 95.0 | 81.2 | 92.5 |
| 17* | 80.0 | 84.0 | 74.0 | 56* | 55.0 | 46.2 | 76.2 |
| 18 | 89.0 | 68.6 | 81.0 | 57 | 80.0 | 77.5 | 78.7 |
| 19 | 96.0 | 94.0 | 96.0 | 58* | 83.7 | 91.2 | 81.2 |
| 20* | 83.0 | 81.0 | 75.2 | 59 | 88.7 | 80.0 | 75.0 |
| 21* | 80.0 | 67.6 | 68.0 | 60* | 75.0 | 90.0 | 80.0 |
| 22* | 49.0 | 56.4 | 57.4 | 61 | 92.5 | 85.0 | 85.0 |
| 23 | 85.0 | 77.0 | 91.0 | 62 | 97.5 | 85.0 | 83.7 |
| 24 | 78.0 | 86.0 | 95.0 | 63 | 82.5 | 68.7 | 56.2 |
| 25 | 87.0 | 59.0 | 80.2 | 64 | 72.5 | 68.7 | 67.5 |
| 26 | 78.0 | 62.0 | 82.0 | 65* | 85.0 | 81.2 | 63.7 |
| 27 | 74.0 | 52.0 | 70.4 | 66 | 68.7 | 63.7 | 50.0 |
| 28* | 63.0 | 67.0 | 86.4 | 67* | 100.0 | 88.7 | 90.0 |
| 29 | 96.0 | 86.0 | 97.0 | 68* | 75.0 | 73.7 | 72.5 |
| 30 | 82.0 | 75.4 | 82.4 | 69* | 67.5 | 73.7 | 61.2 |
| 31 | 89.0 | 80.0 | 92.0 | 70 | 92.5 | 90.0 | 77.5 |
| 32 | 60.0 | 61.0 | 67.0 | 71 | 97.5 | 91.2 | 96.2 |
| 33 | 86.0 | 83.0 | 85.4 | 72 | 100.0 | 91.6 | 75.0 |
| 34 | 90.0 | 83.0 | 96.0 | 73 | 95.0 | 88.7 | 82.5 |
| 35* | 77.0 | 70.0 | 73.6 | 74 | 63.7 | 80.0 | 72.5 |
| 36* | 90.0 | 83.0 | 87.0 | 75* | 78.7 | 76.2 | 70.0 |
| 37 | 76.0 | 58.0 | 79.0 | 76 | 95.0 | 85.0 | 68.7 |
| 38 | 61.0 | 54.0 | 66.0 | 77* | 71.2 | 55.0 | 47.5 |
| 39 | 84.0 | 77.0 | 83.0 | | | | |
| | | | | Total | 6209.8 | 5826.2 | 6073.8 |
| | | | | Ave. | 80.65 | 75.66 | 78.88 |

*Stands for the boys in the group as contrasted with the girls.

textbooks were removed from the tops of the tables and a short test was given to check up on the knowledge acquired during the procedure. Each test consisted of ten questions about important points of structure. They were mimeographed with spaces left for answers. Each question was carefully worded so that only one correct answer could be given, and this was usually only a word or a phrase. This made testing objective. The papers were scored by marking the answer either right or wrong and then reducing the score to a percentage basis for each paper.

In order to test retention of facts, each of the tests was repeated

TABLE II—SUMMARY OF AVERAGES ON DELAYED TESTS BY EACH OF THE METHODS.

| Pupil | Model | Chart | Teacher's Drawing | Pupil | Model | Chart | Teacher's Drawing |
|---|---|---|---|---|---|---|---|
| 1 | 59.4 | 57.4 | 59.0 | 40 | 55.0 | 55.0 | 63.7 |
| 2 | 58.4 | 67.0 | 52.6 | 41 | 61.2 | 70.0 | 80.0 |
| 3* | 39.0 | 50.0 | 42.8 | 42 | 73.7 | 83.7 | 81.2 |
| 4 | 84.0 | 85.0 | 75.0 | 43 | 52.5 | 40.0 | 55.0 |
| 5* | 51.8 | 64.0 | 43.0 | 44 | 36.2 | 44.7 | 62.5 |
| 6* | 65.8 | 45.8 | 59.8 | 45 | 75.0 | 47.0 | 67.5 |
| 7 | 88.0 | 94.0 | 88.0 | 46 | ........ | ........ | ........ |
| 8 | 86.8 | 90.0 | 95.0 | 47* | 56.2 | 41.2 | 41.2 |
| 9* | 60.0 | 69.0 | 55.0 | 48* | 66.2 | 50.0 | 71.2 |
| 10* | 59.0 | 77.0 | 77.4 | 49* | 57.5 | 58.7 | 87.5 |
| 11* | 77.0 | 82.4 | 76.0 | 50 | 52.5 | 58.7 | 42.5 |
| 12 | 61.0 | 50.2 | 35.0 | 51 | 75.0 | 86.2 | 80.0 |
| 13* | 37.4 | 61.0 | 56.8 | 52* | 52.5 | 64.7 | 70.0 |
| 14 | 44.4 | 47.0 | 56.8 | 53* | 46.2 | 38.7 | 72.5 |
| 15 | 60.0 | 74.0 | 82.0 | 54* | 22.5 | 46.2 | 50.0 |
| 16 | 61.4 | 68.0 | 86.0 | 55 | 62.5 | 56.2 | 77.5 |
| 17* | 49.0 | 69.0 | 49.4 | 56* | 71.6 | 26.2 | 50.0 |
| 18 | 60.4 | 71.2 | 80.0 | 57 | 57.0 | 60.0 | 48.7 |
| 19 | 87.6 | 84.0 | 82.0 | 58* | 76.2 | 70.0 | 69.7 |
| 20* | 46.8 | 58.7 | 62.0 | 59 | 72.5 | 62.5 | 71.2 |
| 21* | 70.4 | 58.4 | 36.0 | 60* | ........ | ........ | ........ |
| 22* | 32.0 | 38.7 | 41.4 | 61* | 79.5 | 77.5 | 52.5 |
| 23 | 69.0 | 65.0 | 73.4 | 62 | 78.7 | 86.2 | 82.5 |
| 24 | 71.0 | 68.0 | 84.0 | 63 | 61.2 | 42.5 | 41.2 |
| 25 | 61.0 | 47.0 | 73.6 | 64 | 51.2 | 53.7 | 68.7 |
| 26 | 73.0 | 49.0 | 60.4 | 65* | 71.2 | 65.0 | 75.0 |
| 27 | 79.0 | 61.4 | 76.0 | 66 | 51.2 | 47.5 | 28.7 |
| 28* | 70.0 | 50.2 | 57.4 | 67* | 81.2 | 75.0 | 63.7 |
| 29 | 84.0 | 82.0 | 95.0 | 68* | 42.5 | 38.3 | 38.7 |
| 30 | 65.0 | 53.2 | 52.0 | 69 | 60.0 | 56.2 | 48.7 |
| 31 | 91.0 | 84.0 | 79.4 | 70 | 91.2 | 70.0 | 67.5 |
| 32 | 51.0 | 52.4 | 53.4 | 71 | 87.5 | 82.5 | 78.7 |
| 33 | 72.0 | 75.0 | 74.0 | 72 | ........ | 70.0 | ........ |
| 34 | 78.0 | 57.4 | 81.0 | 73 | 72.5 | 68.7 | 60.0 |
| 35* | 72.0 | 46.8 | 67.0 | 74 | 55.0 | 57.5 | 45.0 |
| 36* | 76.0 | 57.0 | 58.0 | 75* | 78.2 | 55.0 | 62.5 |
| 37 | 63.0 | 40.4 | 50.8 | 76 | 83.7 | 65.0 | 50.0 |
| 38 | 48.7 | 38.7 | 47.2 | 77* | 39.7 | 33.2 | 27.5 |
| 39 | 55.0 | 52.4 | 60.0 | Total | 4724.8 | 4544.2 | 4665.4 |
| | | | | Ave. | 63.84 | 60.59 | 63.05 |

about four weeks after the first presentation. None of the papers were returned but the pupils were informed of their grades.

The arithmetic mean scores for the averages of the entire group of 77 pupils by each method, both for the immediate and the delayed tests were determined. The tables show summaries of the results on immediate tests and delayed tests respectively. Both immediate and delayed tests reveal the fact that pupils learn most by the aid of models, less by the aid of teacher's drawings and least by the aid of charts.

A determination of the probable error of the difference of the means was attemped in order to show whether the differences between the mean scores were large enough to be significant. It was found that the probable error of the difference of the model mean and chart mean was .7, so that the real difference was not 4.99 but 4.99±.7. This is a significant difference. The probable error of the difference between the model mean and the teacher's drawing mean was .7 also. But since the difference found was 1.77, the real difference was 1.77±.7, which is *not* large enough to be significant. The real difference between the chart mean and teacher's drawing mean was found to be 3.22±.9. This is also a significant difference.

The bright versus the dull pupils, based upon their general high school averages, were compared to determine whether the two groups differ in their ability to learn by the three methods. Pupils 4, 7, 8, 11, 16, 19, 42, 59, 62, and 71 were the bright members, while pupils 43, 44, 46, 48, 50, 56, 68, 70, and 77 were the dull members. It was found that the mean scores of these groups came out as follows:

| Bright pupils | Model | Chart | Teacher's Drawing |
|---|---|---|---|
| Immediate | 92.64 | 89.07 | 90.94 |
| Delayed | 79.72 | 81.83 | 81.56 |
| Dull pupils | | | |
| Immediate | 71.36 | 66.36 | 71.42 |
| Delayed | 56.55 | 45.14 | 51.85 |

Pupils 1-39 were advanced pupils in that they had had a semester of botany before the investigation was undertaken, while pupils 40-77 were beginners in botany. It was decided to make a comparison of the scores of these two groups. The following results were obtained:

| Advanced pupils | Model | Chart | Teacher's Drawing |
|---|---|---|---|
| Immediate | 80.81 | 74.79 | 81.29 |
| Delayed | 64.58 | 62.51 | 64.96 |
| Beginning pupils | | | |
| Immediate | 80.57 | 76.56 | 76.41 |
| Delayed | 63.04 | 58.43 | 60.91 |

Still another comparison was made, namely a comparison of the boys versus the girls. The mean scores for each group by each of the three methods may be seen in the following:

| Boys | Model | Chart | Teacher's Drawing |
|---|---|---|---|
| Immediate | 76.78 | 72.94 | 75.67 |
| Delayed | 58.14 | 55.19 | 59.46 |
| Girls | | | |
| Immediate | 82.98 | 77.16 | 80.82 |
| Delayed | 67.32 | 63.80 | 66.44 |

The data throws objective light on the relative difficulty for high school pupils of various plant structures. It was discovered that the morphology of the pine, moss and marchantia reproductive structures are very difficult for high school pupils. Average scores of 62.95, 64.28 and 66.07 respectively were made on these three tests. Beginning pupils did poor work on the composite family and also on flower terms. Average scores of 60.56 and 61.42 respectfully were made.

Correlations between knowledge acquired by each of these methods and the general high school average of each pupil were made. High coefficients of correlations were found. The correlation between the model and the general high school average was found to be $.553 \pm .05$. The correlation between chart and high school average was $.517 \pm .05$. The correlation between the teacher's drawing and the general high school average was $.495 \pm .05$.

Correlations between the methods were also constructed. The coefficients were found to be high in all three cases. The correlation between the model and chart was especially high $.739 \pm .03$. The correlation between the model and teacher's drawing was $.611 \pm .04$. The correlation between the chart and teacher's drawing was $.584 \pm .05$.

The results of this investigation seem to justify the following conclusions:

(1) The visual aids, models, charts and teachers's drawings are of value in teaching pupils of botany details of plant structures, but they are not of equal value.

(2) Botany pupils learn details of plant structure better when models are used as demonstrational aids in teaching these structures than when charts are used.

(3) The difference between the value of models and of teacher's drawings as aids will be greater or less depending upon the teacher's ability to make good diagrammatic blackboard drawings.

(4) It is to the advantage of every botany teacher to endeavor to improve his ability in making blackboard diagrams of plant structures, since the value derived from good diagrams can be made to closely approach, at least, the value derived from models which are frequently very expensive.

(5) Both bright and dull pupils get more help from models and teacher's drawings than they do from charts in understanding plant structures.

(6) Proper training tends to increase the pupils' ability to interpret diagrammatic blackboard drawings.

(7) Both boys and girls learn structures best by the aid of models. Both learn least by the aid of charts.

(8) Girls seem to have a greater power of observation of details of plant structure than do boys.

(9) Incidentally it has been proved that the morphology of certain plants is much more difficult for high school pupils than that of other plants.

(10) The high correlation between each of these three methods and the general high school average shows that all three methods measure ability well.

(11) The high correlation between the methods themselves proves that no one of the methods is much more pleasing than the others to the pupils.

(12) The fact that correlation between the model and the chart is highest indicates that there are more elements in common between the teacher's drawing and either charts or models. Pupils learn details better from the model than from the chart.

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**Slightly more than half, 56 of the 109 persons to whom the degree of doctor of philosophy has been granted by the University of Wisconsin, chemistry department, since the World War, are engaged in industrial work. Previous to the World War the larger number of holders of the Ph. D. degree in chemistry adopted teaching as a profession.**

# THE APPLICATIONS OF MATHEMATICS TO CHEMISTRY.[1]

BY W. CONARD FERNELIUS,[2]

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## PART I. IMPORTANCE OF MATHEMATICS IN CHEMISTRY.

It is in no way unusual for one to speak of the applications of mathematics to chemistry for the latter has long been recognized as one of the exact sciences. However, it is rather doubtful if many people, even mathematicians, realize to how great an extent chemistry is dependent upon her sister science. Any adequate discussion of the applications of mathematics to chemistry would require a large volume while an exhaustive study would necessitate a series of volumes. Lack of space here prevents any mention of matters other than some of the more interesting.

Chemistry concerns itself primarily with the transformations of matter—the change of one substance or group of substances into one or more other substances—and the energy changes accompanying such transformations. By necessity chemistry is also interested in the physical properties (solubilities, melting points, boiling points, etc.) and chemical properties (reactivity, transformations, etc.) of substances. Like every other investigator who collects large numbers of widely dispersed facts, the chemist seeks to classify his data and make generalizations from it in the form of theories and laws. He makes these generalizations both as an aid in remembering facts already obtained and in forecasting other probable facts. The chemist's theory may be only a rule of thumb—merely an aid to remembering—but he seeks always to make it more—a law which he can express mathematically as the dependence of one thing on another. Since the actual dependence of the variables and the dependence implied by the law are not necessarily the same, it is customary to state that a certain equation agrees with the experimentally observed facts within an accuracy of such and such percent. If this percentage is other than very small then the expression, although useful, is not accurate; i. e., it probably does not take into account all the variable factors. When the difference between the "calculated" and the "observed" results lies within the limit of experimental error, then the law is accurate and of great usefulness, although even in such a case one must be

[1]This paper was presented as a term paper in "A Teachers' Course in Mathematics" while the author was a student at Leland Stanford University and is published at the suggestion of Professor W. C. Eells who gave the course.

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continually on guard to improve one's instruments and methods of measurement so as to reduce the limit of error and subject the law to more rigorous tests of validity.

The emergence of the science of chemistry from the darkness of its alchemical origin is marked by the experiments of a noted group of Europeans during the latter part of the eighteenth century in which they determined the weights of the various substances involved in chemical reactions. Thus these investigators sounded out the fundamental logic behind quantitative analysis and paved the way for numerous laws which serve as a foundation for the entire science of chemistry. There is nothing more characteristic of chemical thought than the equation, the shorthand used to represent the different substances involved in a reaction. When hydrogen and oxygen are brought together under certain conditions, water is formed. The chemist writes this reaction,

$$2H_2+O_2 \rightarrow 2H_2O.$$

To him, however, this symbolism tells not only that reaction occurs but also that two molecules of hydrogen react with one of oxygen to form two molecules of water; furthermore, that, at any given temperature, oxygen gas combines with twice its volume of hydrogen to produce water and, if the temperature be greater than that of the boiling point of water, the water vapor will occupy a volume equal to twice that of the oxygen; and, finally, that four relative weights of hydrogen combine with thirty-two relative weights of oxygen to yield thirty-six such weights of water. From these facts one finds by simple mathematical logic that the weight of reacting substances on one side of the equation is equal to that on the opposite side (conservation of matter), that the weights of the different materials undergoing reaction or being formed by the reaction stand in simple proportion to each other,[3] and that the individual atoms composing the molecules each have a definite weight (atomic weight). These laws, all mathematical in nature, are fundamental and upon them has been built practically the entire structure of chemical science.

There is another characteristic of the reaction of hydrogen and oxygen—heat is evolved during their combination. This

[3]Hence, in the reaction, $A+B \rightarrow C+D$, it is possible to calculate in advance, knowing the weight of A, the weight of B necessary for complete reaction with A or the amount of C and D that will be formed by the reaction.

quantity of heat has been measured and found to be 116,120 calories for the molecular weights of substances indicated by the equation; i. e., four grams of hydrogen, thirty-two grams of oxygen, etc. The chemist incorporates the evolution of heat in his equation thus,

$$2H_2+O_2\rightarrow 2H_2O+116{,}120 \text{ cal.}$$

Furthermore, at very high temperatures water vapor shows some tendency to decompose into its elements, hydrogen and oxygen; hence, the amount of water formed by the combustion of hydrogen at any stated temperature must represent the equilibrium between water and its constituents.[4]

The original simple equation now becomes

$$2H_2+O_2\rightleftarrows 2H_2O+116{,}120 \text{ cal.}$$

which indicates that reaction takes place in both directions. We are now in a position to consider some interesting applications of mathematics to chemical reactions.

There is a rule of chemistry known as the Law of Mass Action which states that the velocity of any reaction is proportional to the molecular concentration of reacting substances. Thus for the reaction,

$$A+B\rightarrow C+D,$$

the velocity, $v_1$, of formation of substances C and D is proportional to the concentration of substances A and B, $C_A$ and $C_B$, so that

$$v_1=k_1C_AC_B$$

If the system be a reversible one, as is the case for all equilibria, there is also a reverse action,

$$A+B\leftarrow C+D,$$

whose velocity, $v_2$, is proportional to the concentration of substances C and D, $C_C$ and $C_D$, so that

$$v_2=k_2C_CC_D$$

At equilibrium, however, since the amounts of A, B, C and D all remain constant, $v_1$ and $v_2$ must be equal. Therefore,

$$k_1C_AC_B=k_2C_CC_D$$

or

$$\frac{C_CC_D}{C_AC_B}=\frac{k_1}{k_2}=K.$$

This new constant, K, is called the Equilibrium Constant of

[4]At temperatures other than those measured in the thousands of degrees, the equilibrium value lies so far to the right that the formation of water is quantitative.

the reaction and at any given temperature has a constant value for any reaction. The variation of this constant with temperature is given by the expression,

$$\frac{d(\log_e \mathrm{K})}{d\mathrm{T}} = \frac{\mathrm{Q_v}}{\mathrm{RT^2}},$$

where $Q_v$ is the heat of reaction, R a universal constant and T the absolute temperature. Thus the chemist has at his command by simple mathematical manipulations means to determine the degree of completion of a reaction at any temperature after determining the concentrations of substances involved and a few constants for that reaction.

Chemical processes are classified according to order of reaction; the number of different molecular species whose concentration changes during the course of the reaction is used as the basis for designating the order of the reaction. Thus a first degree process is a monomolecular reaction—a molecule of species A produces a molecule of species B,

$$\mathrm{A} \rightarrow \mathrm{B}(+\mathrm{C}+\ldots).$$

In such a process the rate of change of $x$, the amount of substance A that has undergone reaction up to the time, $t$, is proportional to the amount of A present, or

$$\frac{dx}{dt} = k(a-x), \qquad (1)$$

where $a$ is the amount of A originally present. For a process of the second order,

$$\mathrm{A}+\mathrm{B} \rightarrow \mathrm{C}(+\mathrm{D}+\ldots),$$

$$\frac{dx}{dt} = k(a-x)\,(b-x) \qquad (2)$$

or, if A and B are the same substance,

$$2\mathrm{A} \rightarrow \mathrm{C}(+\mathrm{D}+\ldots),$$

$$\frac{dx}{dt} = k(a-x)^2. \qquad (2a)$$

Similarly, for a trimolecular reaction,

$$3A \rightarrow C(+D+\ldots),$$

$$\frac{dx}{dt} = k(a-x)^3. \qquad (3)$$

Integrating and solving for the constant, these expressions become:

$$\text{First Order} \qquad k = \frac{1}{t} \ln \frac{a}{a-x} \qquad (1)$$

$$\text{Second Order} \qquad k = \frac{1}{t(a-b)} \ln \frac{(a-x)b}{(b-x)a} \qquad (2)$$

$$(A = B) \qquad k = \frac{1}{t} \frac{x}{a(a-x)} \qquad (2a)$$

$$\text{Third Order} \qquad k = \frac{1}{t} \frac{x(2a-x)}{2a(a-x)}. \qquad (3)$$

These equations are extremely valuable because they enable one to conclude after simple determinations of the concentrations of reacting substances during the course of a reaction, a good deal concerning the nature of the change taking place. Suppose an investigator has obtained corresponding values of concentration and time for a certain reaction and wishes to know to what order the process belongs. He has merely to make a plot of time against concentration or some function of the concentration and examine the curve obtained. If the process is first order, then the log of the concentration, log $(a-x)$, gives a straight line; if second order, the recriprocal of the concentration, $1/(a-x)$, gives a straight line; and, similarly if third order, the recriprocal of the square of the concentration, $1/(a-x)^2$, gives a straight line. Surely this is an easy way to decide among the alternatives

$$A \rightarrow B(+C+\ldots),$$

$$2A \rightarrow B(+C+\ldots),$$

and

$$3A \rightarrow B(+C+\ldots).$$

It is hoped that the above examples have conveyed a rough idea of the great importance of mathematics to the chemist

and of the complexity attained in even the simpler phases of the subject. The entire field of physical chemistry, perhaps the most important in the entire science today, is almost unintelligible without a knowledge of calculus and differential equations and practically all branches of higher mathematics are useful. Surely no mathematician has a more highly developed space intuition than does the crystallographer who no longer content with the planes bounding crystals has now delved into the interior of these crystals by means of X-rays and speaks of the positions of individual atoms and of the forces holding the atoms together. In fact, the chemist has become so much of a mathematician that he has set as his goal that state of knowledge which will enable him to sit down at his desk and, knowing the properties which he desires a compound to possess, calculate the structure and composition of that compound and method of preparation and then on the following day go into the laboratory and prepare the compound. As yet the chemist is far from his goal but the amount of his advance as attested by recent books and current articles is surprising.

## Part II. The Teaching of Mathematics to Chemistry Students.

The remarkable progress of chemistry and its rise to prominence both in academic and industrial circles have brought about a feeling of responsibility and pride on the part of the chemist. He is fast laying down requirements for those who would join his fraternity and attempting to carry out tasks, formerly performed by others, in his own way. Recently this tendency has manifested itself in the field of chemical education. There are several subjects which are of vital importance to the well-trained chemist, such as languages and mathematics, and yet which cannot be said to be useful in their entirety. Furthermore, because of the broad and expanding nature of the field of chemistry, the student has a real task during his time at college to equip himself with the necessary facts and skill to admit him to his profession; he has no time to pause by the wayside to enjoy any subject which is not going to be directly useful to him in later years. The result has been that chemists are beginning to sever their dependence upon others, reorganize the subject matter of certain courses and teach only those parts bearing directly upon chemical activities.

This severance from other departments on the part of chem-

istry has been particularly noticable in the case of the languages and mathematics. The average chemist has but one use for languages—the ability to obtain information from foreign publications bearing on his own subject. Hence, he need have only a reading knowledge of the languages in his field (the present doctorate requirement in most universities)—rather a small part when compared to the entire field of language study.

The situation in mathematics is very similar. The chemist uses to a great extent only certain phases of mathematics. Instead of taking courses in mathematics followed by others in the application of mathematics to chemistry, the chemist feels that he should teach his students the mathematics of chemistry with applications paralleling the theory. A good idea, but even one who claims to be a chemist cannot deny that this tendency for isolation is beset with grave dangers.

This tendency is admirably portrayed in J. W. Mellor's text, "Higher Mathematics for Students of Chemistry and Physics."[5] In this work, the author very successfully introduces the student to the calculus, differential equations, analytical geometry, series, etc. by way of material most familiar and interesting to the scientist and his students. One must commend the author very highly for he has done his task well. Furthermore, it is very pleasant for one who thinks chemistry to turn to a mathematics book and find himself on familiar ground—the thing is very tempting.

One cannot help but feel, however, that there is a better solution to the chemist's problem than his divorcing other fields of knowledge and attempting to carry out the whole task by himself. Would it not be better to follow current tendencies in the field of education and adjust matters so that the student comes to college with a better preparation and hence need not hurry so much to gain most of his training in college? Now if the elements of calculus and analytical geometry were introduced into the high school curriculum,[6] it would no longer be necessary to take the student's time in the university to master the fundamentals of higher mathematics. Rather, he could immediately take chemical mathematics and be at that state of manipulative ability so much desired by the chemist. Similarly, a more

[5]Mellor, "Higher Mathematics for Students of Chemistry and Physics," Longmans Green and Co., London, 4th Ed., *1913*.

[6]"The Reorganization of Mathematics in Secondary Education," a report by the National Committee on Mathematics Requirements, *1923*, p. 38-42.

thorough study of languages in high school with an introductory study in the grades sufficient in amount to enable the student to begin university work speaking one language and reading another would be very desirable. The acquirement of the chemical aspects of the languages would then be easy and rapid. Not only would the student gain in time but also in contacts for he could begin using foreign literature at a much earlier period than is possible at present. These recommendations, it would seem, are sound and of some value. If present conditions in other fields are similar to those in chemistry, then the existence of such conditions might well be used as an argument in favor of the introduction of certain subjects into the precollegiate curriculum.

In conclusion, the author wishes to express his thanks to Dr. W. C. Eells for the inspiration which prompted the writing of this article and for his kindness in reading the manuscript prior to publication.

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## OHIO STATE EDUCATIONAL CONFERENCE.

April 4, 5 and 6 are the dates of the Ninth Annual Ohio State Educational Conference at Columbus. "Evaluating Education" will be the keynote of this three-day meeting conducted by the College of Education at the Ohio State University. Each year the attendance materially increases. Last year's gain of 335 pushed the number who took part in the three general and 38 sectional meetings to more than 4,800. Since 1923 the attendance has practically doubled.

To extend the "conference" idea, allowing group interests to have even wider consideration, Friday and Saturday forenoons and Friday afternoon will be given over to sectional group meetings. General sessions will be held Thursday and Friday nights only. The customary Saturday morning general session will give way to sectional meetings.

Groups admitted to the Conference for the first time will be represented this year by sections concerned with adult education, higher education, and attendance supervisors, school nurses and visiting teachers. In addition to the three new groups mentioned, one or more sectional meetings will be given to problems of groups interested in biological science, city superintendents, clinical psychology, commercial education, county superintendents, educational and intelligence tests, elementary principals, elementary teachers, English, geography, high-school principals, history, home economics, industrial and vocational education, journalism, junior high-school principals, kindergarten and primary teachers, Latin, mathematics, modern language, music, non-biological science, parent-teacher association, physical education, religious education, school business officials, school librarians, special education, teacher training, and village and consolidated school superintendents.

## SHALL LABORATORY WORK IN THE PUBLIC SCHOOLS BE CURTAILED?

By W. C. Croxton,

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During the past few years a number of experiments have been carried on with the purpose of studying the relative merits of certain methods of instruction in science. As a result of these studies advocates of the lecture-demonstration method contend that large sums of money are being wasted in the unprofitable purchase of equipment in sufficient quantities for individual laboratory work. The saving of much time by the lecture-demonstration method is also claimed. The issue, therefore, becomes an important one for administrators, science teachers, and students of education generally. It should, accordingly, be viewed from all angles.

We are greatly in need of experimental evidence of the degree of effectiveness of the various teaching procedures and it is not the purpose of this discussion to question the desirability or value of such experiments. Rather is it the intent to call attention to certain limitations of the data and additional aspects of the problem which should be considered before recommending important changes in educational procedures.

The studies of Hunter,[1] Phillips,[2] Wiley,[3], Cunningham,[4] Cooprider,[5] Kiebler and Woody[6] and Anibal[7] dealt largely with the acquisition of facts. The differences obtained by use of the different methods were slight. In most cases the results were slightly in favor of the lecture-demonstration when the tests immediately followed the teaching, while greater retention resulted from the individual laboratory method as evidenced

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[1]Hunter, George William, "An Experiment in the Use of Three Different Methods of Teaching in the Class Room." In School Science and Mathematics, 21:875-890, 1921; 20-24, 1922. "An attempt to Determine the Relative Values of Visual and Oral Instruction in Demonstration and Experimental Work in Elementary Biology." In School Science and Mathematics, 22:22-29, 1922. "The Oral Method Versus the Laboratory Manual in the Laboratory." In School Science and Mathematics, 22:29-32.

[2]Phillips, Thomas D., "A Study of Notebook and Laboratory Work as an Effective Aid in Science Teaching." In the School Review, 28:451-453, 1920.

[3]Wiley, William H., "An Experimental Study of Methods in Teaching High School Chemistry." In The Journal of Educational Psychology," 9:181-198, 1918.

[4]Cunningham, Harry A., Individual Laboratory Work Versus Lecture Demonstration, Master's Thesis. Digest in University of Illinois Bulletin, 18:105-107, 1920. "Laboratory Methods in Natural Science Teaching." In School Science and Mathematics, 24:709-715, and 848-851, 1922. "Technique in Chemistry Teaching." In School Science and Mathematics, 22:356-362, 1924.

[5]Cooprider, J. L., "Oral Versus Written Instruction and Demonstration Versus Individual Work in High School Science." Master's Thesis. Digest in School Science and Mathematics, 22:838-844, 1922. "Laboratory Methods in High School Science." In School Science and Mathematics, 23:528-530, 1923.

[6]Kiebler, E. W. and Clifford Woody, "The Individual Laboratory Versus the Demonstration Method of Teaching Physics." In Journal of Educational Research, 7:50-58, 1923.

[7]Anibal, F. G., "Investigation of Demonstration Versus Laboratory as a Method of Teaching Natural Science." Abstract in Proceedings of the National Education Association, 62:771-772, 1924.

by the delayed recall scores. There is some lack of agreement. Wiley,[3] who states that he demonstrated each experiment while lecturing, concluded that "In every respect the lecture (demonstration) method is the least effective in imparting knowledge to high school pupils." On the other hand Kiebler and Woody,[6] who used a sort of developmental demonstration method and attempted to measure the ability to apply the information and technique gained as well as its acquisition and retention, reached the conclusion that the individual laboratory method possesses no advantages in any of these respects. Cunningham,[4] who has probably done as much along this line as any other worker, states that "It is not safe to make sweeping generalizations as to best laboratory methods from these data" and suggests "(1) A careful analytical study of each individual experiment to determine just what skills and abilities are necessary in mastering that particular exercise; (2) A careful testing and diagnosis on the basis of evidence obtained by the testing of each individual pupil to see if he has these skills and abilities; and (3) the adoption of such methods and technique for each individual as our study of both experiment and student indicates is best." There can be little doubt of the time consuming nature of much of the individual laboratory work. Whether there are outcomes from the individual laboratory experience in the way of self confidence, initiative, habits of working and surmounting difficulties, and what for want of a better term might be called "power" that justify the expenditure of the additional time; these experiments do not adequately determine.

The individual laboratory method as used by these investigators seems to have been of the type where pupils follow the directions in a laboratory manual, with the variation that in some cases the instructions were given orally. If it be granted that the data from these experiments be sufficient and conclusive, it would follow that the lecture-demonstration method excels this formal individual laboratory method for immature minds. It would not establish demonstrations and lectures by the teacher as superior to laboratory procedures in which pupils take the initiative and carry on the activities. This fact seems not to have been considered by these investigators and by Downing[8] who summarized their investigations and recommended the reduction of equipment accordingly. The problem of the place of the laboratory in our educational scheme is a

[8]Downing, E. R., "Comparison of the Lecture-demonstration and the Laboratory Methods Instruction in Science." In School Review, 33:688-697,of 1925.

much larger one than the pitting of one formal method against another. The question of curtailing laboratory investment must be viewed in the light of changing laboratory procedures and curricula.

Students of science education are familiar with the history of the school laboratory. Our older educators doubtless recall that in their public school and college days there were no laboratories in America open to students. The laboratory reached our public schools through the colleges as did most of our curricula. Laboratory procedures similar to those employed in colleges were likewise introduced. High-school pupils executed a certain number of exercises according to directions in "cut down" college manuals. The "experiments" were not undertaken to answer questions where differences of opinion existed among members of the class. The tasks did not have their origin in pupil experiences and interests and they were frequently undertaken with little preparation. We are now in a period of changing laboratory procedures. The laboratory work is less formal and in classes where the manual has not been entirely discarded it is less slavishly followed. In many project courses, the pupil selects his problems, plans his methods and carries out the work with the teacher acting in an advisory capacity. What, then, is the individual laboratory method? Is it the use of a formal type of laboratory manual or is it the individual project, procedures which may be very divergent from an educational viewpoint?

Despite its numerous attacks the project method seems to be emerging from this redirection period with a greatly increased number of enthusiastic supporters. The studies by Garber[9] and Watkins[10] comparing the project method with the more traditional formal laboratory-textbook-recitation method gave results which are in close agreement. The pupils taught by the project method made as high or higher score in subject matter tests based on textbooks, although they were in both cases inferior to the other groups according to their intelligence ratings. In addition, much is claimed for the project method in the way of desirable attitudes engendered. Watkins, whose experiments were fairly extensive and apparently carried out with a great deal of care, concludes that project teaching develops

[9]Garber, Ellinor, "The Project Method in Teaching Chemistry." In School Science and Mathematics, 22:71-73, 1922.

[10]Watkins, Ralph Knupp, "The Technique and Value of Project Teaching in General Science." Doctor's Thesis. Digest in General Science Quarterly, 7:235-256, 1923; 8:311-341 and 387-422, 1924.

greater initiative and independence, teaches pupils to think for themselves and develops the problem solving attitude, encourages a wider range of reading, gives greater opportunity for socialization, provides better for the needs of pupils of varying capacities, insures increased effort on the part of pupils, induces greater learning growth and provides the best opportunity for the teacher to grow while in service.

However, we may differ in our definitions of "project" we are agreed that in this method the pupil, not the teacher, carries on the laboratory work. If the enthusiastic proponents of this method are on the right track, it would be a mistake, indeed, to provide only a set of laboratory materials for the teacher's use in demonstration. When a problem arises all members of the class may be working independently to solve it. Even when each child is working on a separate problem, many of the same articles are often needed by several pupils simultaneously. There is need for less highly specialized expensive apparatus and more working equipment. Moreover, when this method is used, the laboratory may not be reduced in size as Downing advocates for each child must have space to work.

Meister's[11] experiments dealing with the educational value of play with scientific toy units is of interest in a general consideration of the problem. His striking conclusion that "Extracurricular activities in science make for almost as good a knowledge of environmental phenomena as do curricular activities" and that "Boys who participate in both curricular and extracurricular activities excel all others" tend to further emphasize the importance of providing the opportunity for all pupils to come into contact with scientific materials and to work individually. He states that "the chief characteristic about a boy who succeeds in overcoming a difficulty is that he almost always finds a new problem arising out of the old one."

There is opportunity for improvement in laboratory work. It seems likely, however, that this improvement will come through the redirection of pupil activity, rather than the shifting of the activity from pupil to teacher. It is a question whether saving of time and expenditure by this means is true economy. It is one of the most fundamental principles of education that self activity educates. The passive nature of much of our school work is probably properly held accountable for much of the

[11]Meister, Morris, "The Educational Values of Certain Afterschool Materials and Activities in Science." Doctor's Thesis, Digest in SCHOOL SCIENCE AND MATHEMATICS, 22:801-813, 1922, and General Science Quarterly 7:167-180, 1923.

failure to bring about change in pupils' reactions through school training. Teaching is largely directing pupil activity, a principle which has been known since the days of Comenius and one which is proven again and again in our own experiences.

Every man of science knows that the conclusions must be limited to the phase or phases of a problem covered by the data obtained. We have much need to apply this principle in this period of scientific study of education. The science teachers, administrators, and boards of education, upon whom falls the problem of equipping the school laboratory, should avail themselves of the results of all obtainable data. But when this data is examined, its evident limitations should be taken into consideration, lest we take a step backward the accomplishment of which required the combined efforts of our predecessors.

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## RADIO PRODUCES ARTIFICIAL FEVER.

A brand new method of experimentation in physiology that may very likely prove a new method of cure for certain diseases is opened up by recent work at the Albany Medical College by Dr. Helen R. Hosmer. She has been making a careful study of the effects on animals of short radio waves of from 25,000 to 10,000 kilocycles (12 to 30 meters). The effect was noticed when bystanders around a 20-kilowatt, 5-meter transmitter found that their temperature was raised.

Dr. Hosmer has measured the effect of the waves from a special 750-watt transmitter, furnished for the purpose by the Research Laboratory of the General Electric Co., in heating a weak solution of ordinary salt. Such a salt solution is very smiliar to the fluids of the body in its behavior. The rate at which the temperature rose depended on the wavelength and the strength of the solution. With a frequency of 25,000 kilocycles, corresponding to 12 meters, a strength of one part of salt to 2000 of water was heated most rapidly, while with 10,000 kilocycles (or 30 meters) a solution of only half this strength was heated at the fastest rate. The liquid was placed in a tube between two parallel metal plates connected with the transmitter.

When a tadpole was placed between the plates, its temperature rose three degrees in 31 seconds while it was alive and 12 degrees in 2 minutes after it was dead. This was with a single tadpole; when there were a number together the rate of heating was higher. Experiments were also made with rats.

Though Dr. Hosmer points out the extreme danger of exposing human beings to these waves until much more is known about them, she states that it affords a new and important field for the experimental physiologist. Now he can induce fever at will without introducing poisons, bacteria, or other foreign bodies into the blood.

Similar experiments along this same line, but without such powerful apparatus, have been made by Dr. W. T. Richards of Princeton University, and Alfred L. Loomis of the latter's private laboratory at Tuxedo Park, N. Y.—*Science News-Letter.*

## STUDY OF CONTAINERS FOR LABORATORY CHEMICALS.

By M. W. Welch,
*W. M. Welch Manufacturing Company, Chicago, Ill.*

The purity of laboratory chemicals has been the subject of much study for years with the result that economical methods of analysis and purification have reached a high standard of efficiency. In the last few years, the government campaign of simplification and standardization has brought to us the thought of new possibilities in the development of the most serviceable, convenient, and attractive containers for the chemicals themselves.

Data on the subject being incomplete and unclassified, an inquiry was conducted, not by the use of the formal questionnaire method which has become somewhat burdensome to educators, but by hundreds of personal interviews with chemistry teachers. Twenty men, who are University or College graduates and most of them former instructors in High Schools and Colleges, made these interviews, exhibiting samples and getting the teachers' viewpoint on the various types of containers.

Believing that a summary of these findings will be of interest, we are pleased to report briefly the surprisingly unanimous opinions. It was our effort to present the various viewpoints including the question of the relative costs of containers and the relative utility of the definite types of containers.

Question No. 1. Would you prefer transparent or colored bottles such as amber, dark blue, or any other available standard color?

There was an overwhelming preponderance of opinion in favor of the transparent bottle.

From a pedagogical standpoint it is clearly desirable to have chemicals in transparent containers so that students may observe the physical characteristics of the materials. Transparent containers also make it easy to detect gross impurities. A third point brought out in favor of glass is that it keeps chemicals in the best state of preservation, protecting them best from dust and moisture and reducing the danger of contamination from the container itself to a minimum.

The investigation showed that with the exception of a

few chemicals used in elementary chemistry, there is no need for colored bottles. This, of course, does not apply to pharmaceutical preparations, organic chemicals, nor to special lines of analyzed chemicals. It does, however, apply to all but a few of the common chemicals purchased for students' use in elementary chemistry.

Question No. 2. What type of bottle closure do you prefer—cork, screw-cap or glass stoppered?

It was explained that this question was only intended to cover the great mass of comparatively inert liquids and salts and did not apply to the few caustic or corrosive chemicals which necessitated special closure.

The ordinary cork stopper was almost universally condemned as a nuisance and an unsatisfactory bottle closure. The ground glass stoppered bottle was considered too expensive and somewhat impractical both from the standpoint of shipping and from the standpoint of utility on the stock shelves. An overwhelming approval was given to the bottle with the screw-cap that is cork lined, the cork disc being covered with a heavy paraffin paper. The random expressions were that this form was very much superior to the old-fashioned cork, the additional cost negligible and the appearance of the bottles on the stock shelves better.

In view of this convenience, the rapid adoption of the cork-lined screw-cap is not surprising. If one steps into his neighborhood drugstore and buys a bottle of spirits of camphor, he will receive it in a screw-cap bottle which can be opened by twisting the cap and can be closed again as tightly as before it was opened with no injury whatever to the cap. He does not have to try to pry out the cork with a pocket knife and perhaps break off the top of it. The use of the screw-cap bottle in the school laboratory is even more important because when the screw-cap is taken off the bottle, it can be laid on the table without rolling off and is less likely to become contaminated.

Question No. 3. What type of closure and kind of cans do you prefer for those chemicals ordinarily put up in tin can containers, i. e., do you prefer cork, screw-cap, or a friction cap, center opening or side opening, round or rectangular cans?

To our surprise, the instructors as a whole did not prefer tin cans of any kind whatever. There was a spontaneous

and universal request that all chemicals that have for years been ordinarily put up in tin cans such as half gallon quantities of denatured alcohol and a host of semi-deliquescent salts be put into narrow and wide mouth glass containers, the screw cap closure being preferred.

Upon investigation, we were pleased to find that it was possible to supply glass containers at no additional charge and one of the outstanding results of these questionnaire conferences has been the elimination of tin cans from our chemical stock shelves. The total additional cost for the glass containers where the tin cans of both cork and screw cap closures have been used in the past is negligible and the apparent unanimity of condemnation of the tin cans as a container for chemicals on the educational laboratory stock shelves was surprising.

Question No. 4. What type of closure is best for fiber cartons?

Glass is more serviceable and attractive than cartons, but here there is a very real cost difference. In fact, this difference is so great that if glass were to be substituted for fiber, the container would often cost several times as much as its contents. Careful attention to certain details of construction should be given to cartons prepared for the packing of chemicals. The ends should be much heavier than the body of the carton because the ends must stand more abuse. Cartons are considerably improved by being paraffin-lined.

A wrapper seal almost doubles the strength of a carton, and a good carton thus sealed will be in good condition when all the contents have been used. A wrapper label adds very materially to the strength of the container. Also the wrapper permits easy opening of the carton without injury to the top. All that is necessary is to cut the wrapper around the top and lift off the cover. The carton can then be effectively resealed. This type of closure also permits the label to be printed on the wrapper, making it part of the package. This adds to the appearance of the package and prevents the label from ever coming off.

We wish publicly to express our appreciation of the earnest co-operation by the many school officials and instructors in the collection of this material.

## SCIENCE STRIDES FORWARD IN 1928.

### Biology.

A moving picture record of the living rabbit's egg which discloses many new phenomena, hitherto unknown, was obtained by Dr. W. H. Lewis and Dr. P. W. Gregory.

The parathyroid gland plays a large part in the control of sex of unborn offspring, Dr. Simon B. Chandler, of the Loyola University School of Medicine, Chicago, found.

A new vitamin, needed by young trout for normal growth, was discovered in raw liver by a group of biologists at Cornell University, and received the provisional name "Factor H."

Insects neither male nor female but containing characteristics of both sexes were produced in X-ray experiments by Prof. James W. Mavor, of Union College, Schenectady, working in a London laboratory.

Successful crossbreeding of Alaskan reindeer with native caribou and the production of fawns of materially increased weight, was accomplished by the U. S. Biological Survey.

A case of a mare mule which not only bore two healthy colts but had a grandchild was reported by A. H. Groth of Texas A. and M. College.

Canada undertook a census of the animals remaining in her musk-ox herds.

The attempt of the Soviet Government to save from extinction the wisent, Europe's representative of the bison family, failed, since careful searches of the 1,100 square-mile reserve made by naturalists showed no trace of a single living animal.

The first milk a cow produces after giving birth to her calf should be fed to the calf because it contains substances that ward off diseases, Dr. Theobald Smith, noted bacteriologist, reported.

Zinc and boron are needed by plants, Miss A. L. Sommer and Prof. C. B. Lipman found at the University of California.

### Chemistry.

Gluconic acid, a chemical hitherto obtainable only at a price of $100 a pound, was produced at 35 cents a pound by chemists at the Color Laboratory of the U. S. Department of Agriculture, using a species of mould growing on a glucose solution.

Edible fats and fatty acids for soap making were made from paraffin through catalytic methods developed by the chemists of the German Dye Trust.

A magnetic theory of catalytic action in which molecules and atoms are conceived as having two poles like a bar magnet was advanced by Dr. Karl Krauch, German chemist.

Wall board is being manufactured from corn stalks in a special semi-commercial plant set up at Ames, Iowa, by the U. S. Bureau of Standards in cooperation with Iowa State College.

A commercial plant for making paper out of cornstalks was built in Illinois, the first of its kind.

The process for converting wood waste into an edible carbohydrate suitable for hog food devised by Dr. Freidrich Bergius, German chemist, was improved to the point of semi-commercial production.

The U. S. Bureau of Chemistry and Soils has evolved two methods of making from corncobs insulating briquettes to be used as a substitute for cork, especially in small refrigerating units.

A successful substitute fabric has been developed to replace gold-beater's skin in the making of gas cells for airships, and several months' use in the "Los Angeles" shows the new material to be cheaper and fully as good.

## PROBLEM DEPARTMENT.

CONDUCTED BY C. N. MILLS,

*University of Michigan, Ann Arbor, Mich.*

*This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.*

*All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem, sent to the Editor,* should have the author's name introducing the problem or solution *as on the following pages.*

*The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to C. N. Mills, 204 Mason Hall, University of Michigan, Ann Arbor, Mich.*

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## SOLUTIONS.

1031. *Proposed by P. H. Nygaard, North Central H. S., Spokane, Wash.*

Solve for the smallest integral values of $a$ and $b$:

$$a=\frac{938b+647}{229}.$$

*Solved by Raphael Robinson, Berkeley, Calif.*

$$a=\frac{938b+647}{229}=4b+3+\frac{22b-40}{229}.$$

If $(22b-40)/229=c$, then $b=10c+2+(9c-4)/22$.
If $(9c-4)/22=d$, then $c=2d+1+(4d-5)/9$.
If $(4d-5)/9=e$, then $d=2e+2+(e-3)/4$.
If $(e-3)/4=k$, then $e=4k+3$.

Therefore, $d=9k+8$, $c=22k+20$, $b=229k+210$, and $a=938k+863$. For different integral values of $k$, these expressions give all integral solutions of the original equation. For the smallest positive integers set $k=0$, then $a=863$, $b=210$. *Editor:* Some of the solutions gave the negative values of $a=-75$ and $b=-19$.

Also solved by *J. Murray Barbour, Aurora, N. Y.; A. L. McCarty, address unknown; R. E. Morris, Spokane, Wash.; E. de la Garza, Brownsville, Texas; R. T. McGregor, Elk Grove, Calif.; George Sergent, Tampico, Mexico; J. F. Howard, San Antonio, Texas; one unknown reader;* and the *Proposer.* Two incorrect solutions were received.

1032. *Proposed by Glenn F. Hewitt, Fort Wayne, Indiana.*

Two regular hexagons, each side being four feet, form the bases of a hexagonal prism. The altitude of the prism is 12 feet. The lateral edges meet the plane of the base at an angle of 60 degrees. Find the lateral area.

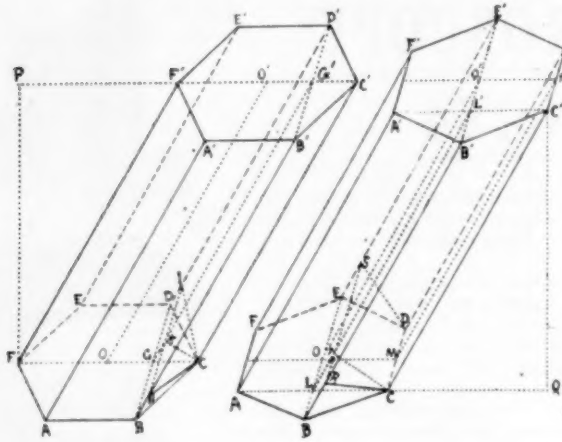
*Solved by George Sergent, Tampico, Mexico.*

Let ABCDEF and A'B'C'D'E'F' be the two equal regular hexagons, lying in parallel planes, OO' their line of centers, or axis.

*First case:* The axis OO' makes an angle of 60° with a radius. Let this radius be OC. The edges are all equal to the side of an equilateral triangle whose altitude is 12 feet. Hence each edge is $8\sqrt{3}$ feet.

The sides AB and DE are parallel to OC. $\angle A'AB=\angle E'ED=\angle O'OC=60°$. The altitudes of the two parallelograms ABB'A' and EDD'E' are each equal to the altitude of an equilateral triangle whose side is 4 feet. Each is $2\sqrt{3}$ feet. The area of these two parallelograms is 96 sq. ft.

The other four parallelograms are equal. We have to compute their altitude. Let GG' be the intersection of the planes O'OC and BDD'B'. G bisects OC and BD. Through C draw the plane $\perp$ to GG', cutting GG' in K, the plane BDD'B' in HI, parallel to BG, and the face BCC'B' in CH, altitude of this face. CH is the hypotenuse of the right triangle CKH.




In the right triangle CKG, $\angle CGK = 60°$. Hence $CK = \sqrt{3}$. BGKH is a rectangle; $HK = BG = 2\sqrt{3}$. $(CH)^2 = (HK)^2 + (CK)^2 = 15$. Then $CH = \sqrt{15}$. The area of the four parallelograms is $96\sqrt{5}$ sq. ft. The total area is $(96 + 96\sqrt{5})$ sq. ft. $= 310.66$ sq. ft.

*Second case:* The axis makes an angle of 60° with an apothem. Let OM, $\perp$ bisector of CD, be this apothem. $\angle O'OM = 60°$. The faces CDD'C' and AFF'A' are rectangles, their areas being $64\sqrt{3}$ sq. ft.

The other four faces are equal parallelograms whose altitudes are to be determined. Let the plane ACC'A' intersect the plane BEE'B' in LL'. LL' bisects OB. Draw through C the plane $\perp$ to LL', cutting LL' in T, the plane BEE'B' in RS, parallel to BE, and the face BCC'B' in CR, altitude of this face. CR is the hypotenuse of the right triangle CTL. $(CR)^2 = (TR)^2 + (CT)^2$. (1)

In the rectangle BLTR, $TR = LB = 2$; in the right triangle CTL, $\angle CLT = 60°$. The right triangles CLB and CTL are similar. $CB : CL = CL : CT$. Hence $CT = (CL)^2/CB = 3$. Substituting in (1) we get $(CR) = 13$. The area of the four parallelograms is $4 \times 8\sqrt{3} \times \sqrt{13} = 32\sqrt{39}$. The total area is $(64\sqrt{3} + 32\sqrt{39}) = 310.66$ sq. ft.

*Editor:* Mr. Sergent gave a second solution in which he uses the Heron formula for the find of the area of a triangle.

Also solved by *R. M. Turril, Maywood, Ill.; Bessie Green-Andrews, Wichita, Kansas.* Three incorrect solutions were received.

1033. *Proposed by the Editor.*

A conical bin is to be made from a circular piece of sheet metal by cutting out a sector of the circular metal, no allowance for lapping. Required the angle of the sector for a maximum capacity, if the radius of the circular piece of metal is R.

*Solved by J. Murray Barbour, Aurora, N. Y.*

Let X be the altitude of the cone, $r$ the radius of its base, and V its volume; and R the radius of the circular piece of metal. $V = (\text{pi})r^2X/3$. Since $r^2 = R^2 - X^2$,

$$V = \frac{(\text{pi})X(R^2 - X^2)}{3}.$$

Place the value of $dV/dX = 0$, and solving for X, gives $X = R\sqrt{3}/3$ for a maximum volume. This value of X gives the arc of the sector cut out as $(2\ \text{pi})(R - r)/R$. Hence the angle of the sector cut out is $(2\ \text{pi})(3 - \sqrt{6})/3$ radians, or 66.06 degrees.

Also solved by: *Raphael Robinson, Berkeley, Calif; R. E. Morris, Spokane, Wash.; R. T. McGregor, Elk Grove, Calif.; Kate Bell, Spokane, Wash.; J. F. Howard, San Antonio, Texas; Raymond Huck, Johnson City,*

# *Patterns 2 and 11*

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# *—JEWELL—*

*Ill.; George Sergent, Tampico, Mexico; Bessie Green-Andrews, Wichita, Kans.; J. R. Adams, Rothville, Mo.,* and by an unknown reader. Two incorrect solutions were received.

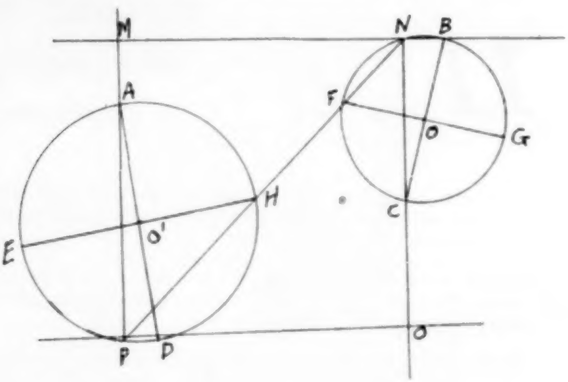
1034. *Proposed by Melvin Weedon, Franklin, Indiana.*

Construct a square so that each side shall pass through a given point. (Altshiller-Court, College Geometry, Exercise 38, page 19.)

*Editor:* Readers interested in this problem should read the discussion on page 400, American Math. Monthly, Oct., 1928.

*Solved by E. de la Garza, Brownsville, Texas.*

A, B, C, D, are the four given points. Join AD and BC, and using AD and BC as diameters, construct circles O and O′. Draw FG and EH,




perpendicular diameters to BC and AD. Draw FH and produce it till it meets circles O and O′ at N and P. Points N and P are the ends of one of the diagonals of the square. Joining NB, NC, PA and PD, the square MNOP is completed. The figure MNOP is a square since the four angles adjoining the diagonal NP are 45.

*Comment:* Instead of having joined AD, BC, we could have joined AB, DC or AC, DB, and we could have determined diagonal PN drawing FH or FE, GH or GE. So there are twelve possible solutions of this problem. In the particular case that points F, H, coincide, the number of solutions will be indeterminate, and any line drawn through H, F, will give a solution. The problem is also possible, when the four given points are on the same straight line.

Also solved by *J. F. Howard, San Antonio, Texas; Samuel Welkowitz, New York, N. Y.;* and by *George Sergent, Tampico, Mexico.*

1035. *Proposed by I. N. Warner, Platteville, Wis.*

A clock loses 5 minutes each day of 24 hours. The clock is set right at noon on Monday. What is the true time on Thursday when the clock shows noon?

*Solved by Raphael Robinson, Berkeley, Calif.*

While the clock runs 23 hr. 55 min., the true time is 24 hr. Hence one minute of clock time is equal 288/287 min. true time. From Monday noon to Thursday noon the clock loses 15 minutes of its own time. Then the true time is 15 min. 3.1 sec. past noon.

Also solved by *J. Murray Barbour, Aurora, N. Y.; J. F. Howard, San Antonio, Texas; E. de la Garza, Brownsville, Texas; one unknown reader; Joseph Daoust, David F. Bender, Robert Heckman, Spokane, Wash.* Two incorrect solutions.

1036. *Proposed by E. de la Garza, Brownsville, Texas.*

A father, upon the beginning of his son's High School education, deposited 10,000 dollars with a bank, at 4% compound interest, converted semi-annually. The money was not touched during the first four years;

but at the beginning of the fifth year and continued for six years, 500 dollars were drawn every six months. Find the amount left in the bank at the end of the tenth year, when it is supposed the son left College.

I. *Solved by Gordon Whitaker, Spokane, Wash.*

$10,000.00 plus compound interest at 4% for four years compounded semi-annually equals $11,716.59. Subtract $500 and multiply by 1.02. Perform the subtraction and multiplication alternately twelve times. The result is $8,019.29.

II. *Solved by J. F. Howard, San Antonio, Texas.*

Balance at the end of 10 years is given by the following: $10000(1.02)^{20} - [500(1.02)^{12}+500(1.02)^{11}+ \ldots +500(1.02)] = 10000(1.02)^{20} - 500(1.02)$

$$\left[\frac{1.02^{12}-1}{1.02\ \ -1}.\right]$$

Using tables we get

$$\$14{,}859.61 - \$6{,}840.31 = \$8{,}019.30.$$

Also solved by *Charles Means, Spokane, Wash.; George Sergent, Tampico, Mexico; Gordon Fuller and Charles C. Wagner, Ann Arbor, Mich.* Four incorrect solutions were received.

## PROBLEMS FOR SOLUTION.

1049. *Proposed by R. T. McGregor, Elk Grove, Calif.*

A and B are two fixed points. CD is a fixed line parallel to AB. X and Y are two variable points on CD such that XY is of constant length. AX and BY meet in P. Show that the locus of P is a straight line parallel to AB.

1050. *Proposed by Norman Anning, University of Michigan.*

A student finds for

$$\sqrt{1-4X} = 1 - 2X - 2X^2 - 4X^3 - 10X^4 - 84X^5 - \ldots$$

He infers that the coefficients of all succeeding powers of X will be negative integers. Prove that he is right.

1051. *Proposed by Nathan Altshiller-Court, University of Oklahoma.*

Through a given point on the bisector of an angle to draw a line so that the segment intercepted on it by the sides of the angle shall have a given length.

1052. *Proposed by Samuel I. Jones, Nashville, Tenn.*

Write any number of four figures in descending order. Reverse the order of the digits and subtract. Again reverse the order of the digits and add. The sum is always 10890. Why?

1053. *Proposed by George Sergent, Tampico, Mexico.*

Given four points A, B, C, and D; to draw through A a line such that, if the perpendiculars BQ, CR, DS, are drawn to it, the sum of these perpendiculars is equal to a given length.

1054. *Proposed by the Editor.*

Conditions are such that a ball falls 50 feet and rebounds 25 feet; then falls 25 feet and rebounds 12.5 feet, and so on. Assume that the ball comes to rest, find the distance through which it moves, and the time it takes to come to rest. Use $g = 32.2$.

In the year 1926 there were 20,984,002 pupils enrolled in public, and 2,143,100 in private elementary schools including kindergartens; 3,786,071 in public, and 346,054 in private secondary schools; 252,907 in public, and 17,209 in private teacher-training institutions; 280,437 in public, and 486,704 in private colleges and universities excluding preparatory students. This made a total of 28,296,484 pupils in such schools in the United States. The total number of teachers employed in all types of schools is 977,291. The total cost of maintaining and operating these schools is reported as $2,744,979,689; and the total value of school property is $8,125,085,472, which amount includes endowments valued at $1,061,589,042.—*Department of Interior.*

## FOREST DEVASTATION.

Out of 822,000,000 acres of virgin forest only about one-eighth remains. Half of that remaining eighth, roughly speaking, is held by the Government and is safe from devastation. The rest is being cut and burned with terrible speed. And there is nowhere in the world anything like a sufficient supply of the kinds of timber we use to take the place of what we have destroyed.

Forest fires are steadily growing worse in America, and fire prevention is absolutely indispensable. But the axe carelessly used is the mother of forest fires. The axe and not fire is our greatest danger. Until the axe is controlled there can be no solution of the fire problem, or of the problem of forest devastation.

Over the National Forests, which cover one-fifth of our ultimate possible timber-growing area, we have established Government control of the axe. These forests are safe, they are well handled, and they will produce larger and larger crops of timber as time goes on. Over the other four-fifths of our forest land the axe holds unregulated sway.

Either we must control the axe on these privately owned lands, or the forests that are left will follow the road of those that are gone already.

The lumber industry is spending millions of dollars on propaganda in the effort to forestall or delay the public control of lumbering, which is the only measure capable of putting an end to forest devastation in America. It is trying to fool the American people into believing that the industry is regulating itself and has given up the practice of forest devastation.—*Gifford Pinchot.*

## ALASKA'S GOLDEN AGE UNEARTHED.

Alaska, like Greece, had its golden age, when the people attained the high point of their culture and then dropped to a less admirable level. Evidence of this prehistoric golden age in the Arctic has been brought back to the Smithsonian Institution by Henry B. Collins, Jr., who conducted an expedition to St. Lawrence Island this summer for the Smithsonian and for the American Association for the Advancement of Science.

On the narrow strip of land called St. Lawrence Island, Mr. Collins found a remarkable mound about 20 feet high and large enough to be the site of a compact village. The mound was composed of trash, the refuse and sweepings from an entire village over a period of many centuries. Animal bones and broken tools, bits of ivory and whalebone, pieces of wood carved in fantastic designs, all were mixed in with a binding of earth and permanently hard and frozen from the cold climate.

The most surprising moment in the digging came when the frozen bodies of some of the oldest inhabitants were discovered encased in ice. Six children had been buried there in the side of the mound, each one dressed carefully in his fur and feather garments. The place where they lay happened to become filled with water, which froze, thus preserving the bodies through many centuries. This is the only time that human bodies have been found in such condition, Mr. Collins states.

Ruins of houses made of driftwood and whalebone were in the top layer of the great mound, Mr. Collins said, in describing his excavation of the site. Digging to the bottom of the mound, he found the ruins of the homes of the oldest inhabitants. To reach the most deeply buried deposit, where the oldest layer of ruins lay, Mr. Collins had to dig six feet below the reach of the storm tides. In other words, he explains, the land has sunk since those houses were built on the beach, and this in itself indicates the passage of considerable time.

This oldest layer of houses dates back to pre-Russian days, the ethnologist declares. They are surely 300 years old, and more likely are nearer to being eight centuries old. The village is the most extensive Eskimo settlement ever excavated.

Many harpoons and other tools and weapons were brought back to the Smithsonian collection. Objects displaying the finest art in carving and design were taken from the lowest and oldest level of the mound. These were made in the days of the highest Eskimo culture. The precision of the lines and the fine designs used indicate that these inhabitants were far more clever with their hands and had a keener sense of beauty than any of their descendants in the Arctic. Whether they were some of the "first Americans," some pioneer Asiatics who brought knowledge and skill to the new world, cannot yet be stated, Mr. Collins says. But it is certain that the Eskimos of historic times have lost a heritage of finer things, as the simpler carvings in the top layers of the mound show.

Present-day Eskimos, possibly direct descendants of the artists, came to the island and helped the scientist excavate. In some cases they were able to enlighten him as to the use of the peculiar articles discovered in the deserted village.—*Science News-Letter.*

## BOOKS RECEIVED.

Electrical Engineering Laboratory Practice by Oskar E. Edison, Associate Professor of Electrical Engineering in the University of Nebraska, and Ferris W. Norris, Associate Professor of Electrical Engineering in the University of Nebraska. Cloth. Pages ix+276. 14.5x23 cm. 1928. Ginn and Company, 15 Ashburton Place, Boston. Price $2.80.

Chemical Reactions and Their Equations by Ingo W. Hackh, Professor of Chemistry, College of Physicians and Surgeons, San Francisco. Second Edition revised. Cloth. Pages x+145. 12x19 cm. 1928. P. Blakiston's Son & Company, 1012 Walnut Street, Philadelphia. Price, $2.00.

A Brief Course in Biology by Walter H. Wellhouse, Associate Professor of Entomology, Iowa State College, and George O. Hendrickson, Instructor in Zoology, Iowa State College. Cloth. Pages vii+200. 12.5x19.5 cm. 1928. The Macmillan Company, New York.

The New World, Problems in Political Geography by Isaiah Bowman, Ph. D., Director of the American Geographical Society of New York. Fourth Edition. 257 Maps. Cloth. Pages v+803. 15.5x24 cm. 1928. World Book Company, Yonkers-on-Hudson, New York. Price $4.80.

Modern Life Arithmetics, Books One, Two and Three, by John Guy Fowlkes, Professor of Education, University of Wisconsin, and Thomas Theodore Goff, Professor of Mathematics, Whitewater Normal School, Whitewater, Wisconsin. Book One, Cloth. xvi+435 pages. 13x20 cm. Price 80 cents. Book Two, Cloth. xvi+402 pages. 13x20 cm. Price 76 cents. Book three. Cloth. xvii+445 pages. 13x20 cm. Price 76 cents. 1928. The Macmillan Company, New York.

Algebra Work-Book by John Guy Fowlkes, Professor of Education, University of Wisconsin, Howard Baker Kingsbury, Head of the Department of Mathematics, West Division High School, Milwaukee, Wisconsin, Raymond Randell Wallace, Instructor in Mathematics, West Division High School, Milwaukee, Wisconsin, and Thomas Theodore Goff, Professor of Mathematics, State Teachers College, Whitewater, Wisconsin. Paper. Pages iv+199. 21x27.5 cm. 1928. The Macmillan Company, New York. Price 80 cents.

Workbook for Grade VI to Accompany The Buckingham-Osburn Searchlight Arithmetics, Book Three, Part II, by B. R. Buckingham, Graduate School of Education, Harvard University, and W. J. Osburn, College of Education, Ohio State University. Paper. Pages ii+110. 20x27.5 cm. 1928. Ginn and Company, 15 Ashburton Place, Boston. Price 36 cents.

Report of A Survey of The Public Schools of Shelbyville, Kentucky. Made by The Bureau of School Service, University of Kentucky. Survey Staff: Dale Russell, Floyd W. Reeves and C. C. Ross. Paper. 191 pages. 15x23 cm. The University of Kentucky, Lexington, Ky. Price 50 cents.

Instructional Tests in Arithmetic by Raleigh Schorling, Head of Department of Mathematics, The University High School and Professor of Education, University of Michigan, John R. Clark, The Lincoln School, Teachers College, Columbia University, and Mary A. Potter, Supervisor of Mathematics Public Schools, Racine, Wisconsin. Paper. 13x20.5 cm. World Book Company, Yonkers-on-Hudson, New York. Fifth Grade vi+57 pages. 65 tests. Price 24 cents. Sixth Grade vi+66 pages. 77 tests. Price 24 cents. Seventh Grade vi+65 pages. 69 tests. Price 24 cents. Eighth Grade vi+78 pages. 86 tests. Price 28 cents.

Parents' Questions, My Child Will . . . My Child Won't . . . What Shall I Do? Paper. 13x19 cm. Child Study Association of America, 54 West 74th Street, New York City. Price 25 cents.

A Selected List of Books for Parents and Teachers. Selected and compiled by the Parents Bibliography Committee of the Child Study Association of America. Paper. 11.5x18.5 cm. 1928. Child Study Association of America, 54 West 74th Street, New York City. Price 25 cents.

Child Study Discussion Records, Development—Method—Techniques by Margaret J. Quilliard, Director of Field Work. Paper. 74 pages. 21.5x28 cm. 1928. Child Study Association of America, 54 West 74th Street, New York City, Price 75 cents.

## BOOK REVIEWS.

*College Chemistry, by Neil E. Gordon, Professor of Chemical Education, Johns Hopkins University, Formerly Professor of Chemistry, University of Maryland.* First Edition pp. ix+516. 15x21x2.25 cm. Illustrated. Cloth. 1928. $2.96. World Book Co.

Here is a new thing, a special text for college students who have had in secondary school substantially the content of the Standard Minimum Outline in chemistry suggested by the committee of the American Chemical Society. The text is designed to bring these students into step at the end of the year with those who have begun their chemistry in college. Less time will, of course, be required to do this than to train the unprepared students. Here we have a chance to avoid duplication of effort and of credit. In case a five hour course must be given both types of students this text provides a brief course in qualitative analysis for the use of the class in the additional time at their disposal.

Part one deals with the fundamentals of chemistry such as the structure of matter, some of the laws of chemistry, properties of gases, Molecular and atomic weights. The second unit of part one deals with acids, bases and salts, solutions, ionization mass action, equilibrium. The third section considers atomic weights and atomic numbers, the periodic classification and electrons and chemical reactions. Next the nonmetallic elements are studied family by family, the halogens, carbon family and nitrogen family. Colloid chemistry completes part one. Part two presents the metals by families after an introductory unit on the electro motive series, ores and metallurgy and the analytic groups of metals. The latter part of the book contains a brief course in qualitative analysis and a concluding chapter on the rare gases. Enough has been said to show that we have in this text a thorough going course such as should be built upon any adequate high school course. F. B. W.

*Man the Animal, William Martin Smallwood, Professor of Comparative Anatomy in Syracuse University.* xiv+235 pp. The Macmillan Company, New York. 1927.

This book serves a useful purpose in providing fundamental and useful information about ourselves in a form easily understood and in a straightforward matter-of-fact way which should appeal to the general reader. The book is not a text, yet it discusses biological principles and makes clear to the reader the laws of life and shows how these laws apply to man and to other living things. The person whose training has not been along biological lines will appreciate the value of this work as it does not require an extensive technical background. Jerome Isenbarger.

*Fundamentals of Biology by Arthur W. Haupt, Assistant Professor of Botany in the University of California at Los Angeles.* xii+358 pp., 256 illustrations. $3.00. McGraw-Hill Book Company, Inc., 370 Seventh Ave., New York, 1928.

The material of this text has been used with large classes of college students, mainly freshmen. The author has been guided by the conviction that a beginning course in general biology should be cultural rather than technical, especially if the large number is made up of students who will not specialize along biological lines. It seems to be the intention to make the course fundamental in setting up a point of view rather than furnishing a large body of knowledge about plants and animals. This certainly complies with the demand for emphasis of principles rather than information. There is an unmistakable modern trend in this direction. An introductory course in general biology should be sufficiently popular to attract a large number of students especially since the training which biology offers is fundamental as a background for a liberal education. Half of the book deals with morphology and physiology of living things, while the other half covers in an elementary way genetics, ecology and organic evolution. Whether the student continues his study of biology beyond the elementary course or drops it with this study, the book serves as a foundation and provides the perspective which the beginning student needs. Jerome Isenbarger.

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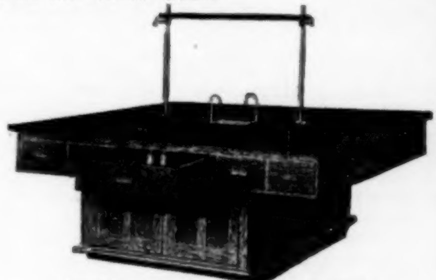

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*Fundamentals of Modern Chemistry, by Herbert R. Smith, M. A., Lake View High School, Chicago, and Harry M. Mess, B. A., Nicholas Senn High School, Chicago.* First Edition. pp. vii+266. 12.5x18.5 cm.

Line drawings and colored spectroscopic frontispiece. Cloth. 1928.

Henry Holt & Co.

This book by two well known and successful teachers of high school chemistry is intended to give the student the fundamentals of general inorganic chemistry unaccompanied by the mass of detail that is usually found in high school chemistry texts. We note above that there are but 266 pages instead of the five or six hundred so often found. The reviewer feels that the authors are on the right track in insisting on a more thorough study of the fundamentals of the subject in place of the memorizing of a huge mass of detailed information. This book is so different from the usual type that high school teachers of chemistry should ask to see it.

F. B. W.

*The Engineer, His Work and His Education by Robert Lemuel Sackett, Dean of Engineering, The Pennsylvania State College.* Cloth. Pages vii+196. 13x20 cm. 1928. Ginn and Company, 15 Ashburton Place, Boston. Price $1.40.

The aim of the author has been to give prospective students of engineering some definite information of the necessary qualifications for success in engineering and of the work required in preparation for this profession. He points out the necessary considerations in selecting a vocation, enumerates the essential qualifications for engineers, gives some directions for self appraisal, and presents tables and charts showing remuneration and progress in the profession and in various lines within the profession.

The chapter on the college course in engineering contains much information for high school boys who think they want to be engineers. This is followed by brief discussions of each of the various branches of engineering. A short, interesting history of engineering from the Ptolemies to the present, and biographical sketches of a dozen great engineers complete the book. G. W. W.

*Introductory Mathematics, by Joseph Eugene Rowe, Ph. D., Professor of Mathematics in the College of William and Mary.* Cloth. Pages vi+285. 15x23 cm. 1927. Prentice-Hall, Inc., New York. Price $2.50.

This textbook of freshman mathematics is an attempt at correlated or unified mathematics but the unification consists principally in introducing into a text book of college algebra certain chapters from other branches of mathematics, some of which may be omitted without destroying the sequence. The initial chapter on college arithmetic starts the student out with familiar ideas but quickly leads him into the theory underlying the operation of computing machines, the computation of error, and other topics stressed in modern applications of arithmetic. A deviation from the trodden path is taken by devoting a chapter to the use of the plane trinometer, which serves as an introduction to the chapters on trigonometry. In the chapters on curves and equations the author has ably condensed into a few pages a sufficient amount of analytical geometry to equip the student for calculus and scientific applications. The final chapter on instantaneous variation introduces the student to the work of the second year and is designed to stimulate interest in more advanced courses. A general method of solving the quadratic, the cubic and the biquadratic equation, originated by Professor E. J. Oglesby of New York University, is incorporated into the chapter on advanced algebra. The book contains an ample supply of exercises ranging in difficulty from the most simple applications of the principles developed to some that will test the ability and ingenuity of the superior students. G. W. W.

## IMPRISONED LIGHT.

By Edwin E. Slosson.

Can you conceive of a thing moving perpetually towards a particular point with the greatest possible speed and yet never being able to reach the point because the nearer it gets the slower its approach?

Well, whether you can conceive of it or not, this is what you are expected to accept among the other curious consequences of Einstein's theory of relativity. If a mass of matter, say a stray stone or a shooting star, travelling through space, passes close to the sun, it will be pulled a bit out of its straight course and, unless it is going by too fast to be stopped, it will come around the sun in a spiral, getting closer and closer each time around until it finally falls in. Or, if it is going a little too fast to fall, it will continue to revolve forever around the sun like a miniature planet.

All this about the behavior of falling bodies has been known since the time of Newton. But Einstein first surmised, what eclipse observation subsequently proved, that a ray of light behaves in the same way. If a ray of light from a star passes close to the sun it is pulled a bit out of its straight course, and would fall into the sun or become its satellite if the light did not travel at too high a speed, in fact at the highest possible speed. But the sun is too big and bulky to lasso a ray of light as it flies by at the rate of 186,000 miles a second. If the sun were solider, as small as one of the minor planets with its present weight, it might capture light and hold it in perpetual captivity.

Now, according to modern notion, all matter is made up of atoms and each atom is constructed like the solar system but with this difference, that nearly all of the mass of the entire atom is concentrated in the central nucleus which serves as the sun of this atomic system. Here matter is intensely condensed into an almost inconceivably small sphere. If we regard it for convenience in calculations as a mere mathematical point, we shall reach the remarkable result that a ray of light headed toward it would never reach it. It would circle around the nucleus forever in an unending spiral, continually coming closer but never getting to the central point in all eternity. For, as it figures out, the nearer the light gets to the center the longer it takes to make the next to the inner circle though its velocity remains the same.

It may aid you to get a conception of this Einstein idea of space and matter if you try this simple experiment. Stretch a sheet of thin rubber like that of a toy balloon over a ring frame such as the ladies use for embroidery. The smooth, flat surface represents empty space, and a little worm making his way across it in a straight line could serve as a ray of light. Push your finger up on the underside and make a hump. This slows up the progress and diverts the direction of the travelling worm as he crawls up its slope. Such humps and hillocks stand for the particles of matter which impede and pervert the passage of light by causing curves in the surrounding space. Now stick a pin up from below, pulling up the rubber by the head like a mountain peak with sides increasing in steepness toward the top till they become perpendicular. To a worm such a mountain peak would be as high as heaven, and if he attempted to climb it he would find it harder and harder to ascend the farther up he got.

Do you get the idea? Perhaps you don't. Perhaps nobody can. But it may be true. The universe is not limited by our imagination. —*Science News-Letter.*

## FILMS OF GOLD SHOW ELECTRONIC WAVES.

A thin film of pure gold, far thinner than the thinnest gold leaf, affords new evidence that electrons are waves, or at least, accompanied by waves. Electrons, the building blocks of which atoms are supposed to be made, were formerly thought of as being like small particles, but modern physicists think that they more nearly resemble waves like light or even radio waves; though much shorter in length, or higher in pitch.

Prof. George P. Thomson, of the University of Aberdeen, and son of Sir J. J. Thomson, one of the most eminent of present-day English physicists, has made the gold-film experiments, which he recently reported to the Royal Institution. A thin film of metal, such as he used, is a screen of molecules that permits the physicist to tell waves from particles. The arrangement of the gold molecules forms a lattice. If a stream of tiny particles is aimed at the screen, they hit molecules at a variety of angles, and so the stream emerges from the other side spread out as a cone. But waves are affected differently. When they go through such a screen they prefer to bend at certain angles. Therefore, if a photographic plate, which is darkened by the electrons, is placed a short distance back of the gold film when the electrons are passed through, a black spot will appear on the plate, surrounded by a series of concentric rings. The black spot represents the bulk of the electrons, which pass through without deviation, the rings represent those which are bent at various angles.

In performing this experiment, Prof. Thomson obtained exactly this effect. Furthermore, to prove that it was not due to light, which is known to behave in a similar manner, he repeated the experiment with a magnet nearby. Electrons are pulled out of their course by a magnet, while light is not. With the magnet, the rings were displaced, as they should be if the effect was due to the electrons. So it is demonstrated rather conclusively that a stream of electrons contains waves. Whether these waves are the electrons themselves, or merely accompany the real electrons, is still a speculation. However, he has measured their wave length and has found that their pitch is more than a million times higher than that of visible light, far higher than that of X-rays, and, except for the cosmic rays, higher than that of any known radiation.

But Prof. Thomson points out that the electron waves are not like light waves. Even if they were as low in pitch as light waves, they would not be the same. They travel at different speeds, the electron waves are bent by electric and magnetic fields, while ordinary light is not, and their penetrating powers are quite different. "If they are actual motion of an ether," he says, "it must differ in some way in the two cases."—*Science News-Letter.*

## DIPHTHERIA IMMUNIZATION.

Diphtheria immunization clinics were held in 27 public schools, in 14 parochial schools, and in other centers in Albany, N. Y., during the school year 1927-28, and toxin-antitoxin was administered to 8,275 children, of whom 2,261 were of preschool age. A diphtheria epidemic in one section of the city gave impetus to the campaign for immunization of all children of the community. The Albany County Medical Society, the Guild for Public Health Nursing, school and city nurses, and volunteer agencies cooperated with the health officer of Albany, the medical director of schools, and the school personnel in giving the treatment.—*School Life.*

### NEW AIRSHIPS TO DWARF GRAF ZEPPELIN.

While the Graf Zeppelin, world's largest airship, dwarfs her sister, the U. S. S. Los Angeles, American designers and enthusiasts are looking forward to 1931, when the all-American ZRS-4, an airship nearly twice the capacity of the Graf Zeppelin, will take the air. A little less than a year later the ZRS-5, a sister ship from the same mould will be produced here in America by the Goodyear Zeppelin Corporation as the result of a contract signed by the U. S. Navy just a few days before the Graf Zeppelin left Germany.

Even earlier, the Graf Zeppelin's world airship title will be challenged, for in England two airships, both 5,000,000 cubic feet in capacity, are nearing completion. They are John Bull's bid for supremacy in the air lanes as well as on the sea's surface. America may expect visits from the R-100 and R-101 in the spring although they may be flight-tested on the air routes to Egypt, India and Australia for which they were designed.

(Continued on page 112.)

## NEW AIRSHIPS TO DWARF GRAF ZEPPELIN.

(Continued from page 109.)

Not discounting the achievements of the Graf Zeppelin's flight, airship experts note that the new German airship is an enlarged edition of the ZR-3, now the Los Angeles, which four years ago made the same trans-Atlantic crossing from Friedrichshafen to Lakehurst on its way to join the U. S. Navy. The Graf Zeppelin is 771 feet long instead of 658 feet. The diameter of the Graf Zeppelin is only ten feet greater than that of the Los Angeles. Both have five engines and their external appearances are similar. The principal difference in the interior is accommodation for the gas fuel ballonets at the bottom of the large envelope and an extra corridor or "cat walk" running the length of the ship.

The new Navy airships when completed will be only fourteen feet longer than the Graf Zeppelin but they will be 132.9 feet in diameter and hold 6,500,000 cubic feet compared with the Graf Zeppelin's 3,708,000 cubic feet. The American ships will incorporate some new design factors that promise to make them unique.

Due to the use of inert helium instead of explosive hydrogen for inflation, it will be possible to place the eight engines inside the hull. Engine specifications have not been announced but it is considered probable that gasoline will be abandoned for heavy oil fuel. The internal engines will allow the ship to slip through the air with less resistance and there will be less danger of the engines being torn off in a severe storm. A complete airplane hangar will be housed within the hull from which five airplanes can be launched from a trapeze, like performers at a circus.

The frame work of the new airship will have a strength unequalled in any other design. Made of duralumin, the favorite airship metal, because of its lightness, every portion of the frame will be close to corridors and passageways and accessible for inspection and repair even during flight.—*Science News-Letter.*